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Genetic and economic factors in sheep production

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INTRODUCTION

Flock owners and research personnel have long recognized the need for evaluating the goals of a selection program in terms of possible effects on the profit potential of individual sheep enterprises. Tentative selection programs have been advanced by many workers in the field of genetics and animal breeding, but very few if any of these programs have been evaluated relative to the profit structure of the sheep industry or of the individual enterprise.

Previous work in sheep breeding has been concerned primarily with estimating phenotypic and genetic parameters of economically important traits in experimental flocks. These estimates have then been used to develop selection indexes for use in obtaining as much genetic progress as possible from the amount of selection that can be practiced. The construction and use of a selection index as applied to farm animals was developed and described by Hazel (1943). Pertinent principles and procedures used in a selection index are widely known and need not be outlined here. Essential to the development of an index are estimates of economic values and estimates of heritabilities and phenotypic and genetic correlations of the traits being considered for selection. The economic value of a trait was described by Hazel as being the amount by which profit may be expected to increase for each unit of improvement in the trait under consideration in an index.

Previous work in agricultural economics concerning sheep production has been concerned with analyses and recommendations relating to the management and financing of sheep enterprises. Estimates of economic values are not available from this field because traits of interest to workers in animal breeding have not been focal points of interest to economists.

Stonaker (1960) has referred to the evaluation of the relative economic importance of traits as something of a no man's land or an area which the economist has not investigated because he is interested more in average results than in the variations between individual animals as they may fit a particular economic need. The geneticist on the other hand has relieved himself of the responsibility for evaluating the relative economic importance of traits by confining his attention completely to the biological aspects of animal improvement.

Little has been accomplished in closing the gap between the genetics and economics of sheep production so as to develop well rounded programs for sheep improvement which are sound economically. Previous sheep breeding studies have pointed out the need for considering profit of an individual enterprise in arriving at economic values for use in a selection index, but difficulty was encountered in attempting to evaluate the influence of a one-unit change in a trait on profit. As a consequence, most workers have used a simplifying assumption that higher potentials of production can be attained through selection without an increase in the cost of production.

The objectives of this study were: (1) To describe and develop profit potential equations for some of the more common types of sheep enterprises. (2) Evaluate the profit potential equations for realistic combinations of prices and variable factors. (3) Relate the changes in profit potentials to changes in traits considered in selection programs for sheep. (4) Discuss the application of the findings of the three preceding objectives to the selection of replacement stock for increased genetic gains in sheep production.

REVIEW OF LITERATURE

The sheep was probably one of the first animals to be domesticated and man has long relied on sheep for clothing and food. According to Terrill (1958), many of the methods of sheep improvement common during the last five decades such as the formation of breeds and types, and selection for increased production are improvements on practices which began possibly 7,000 to 8,000 years ago. Efforts of most agricultural research in sheep production in the last fifty years have been directed to developing new methods and adapting older methods of sheep improvement to meet changing needs and diverse environments in which sheep are maintained.

The United States had an estimated 29,793,000 sheep and ranked seventh in the world for numbers of sheep in 1963. According to the USDA (1961), total sheep numbers in the United States were relatively high in the thirties and reached a peak of about 56,000,000 in 1942. Numbers rapidly declined to 29,826,000 in 1950 and remained fairly constant until 1957. After 1957 sheep numbers increased slightly for a few years before decreasing again to the present low level. The National Wool Act of 1954 was passed in an effort to stimulate an increase in the number of sheep maintained in the United States.

Hazel (1943) introduced the technique of computing genetic correlations and of incorporating genetic and economic information in selection indexes for swine. Since that time selection indexes have been developed for Rambouillet weanling lambs by Hazel and Terrill (1946), for rating farm flock ewes on their productivity by Winters, *et al.* (1946), for Australian Merinos by Morley (1950), for the New Zealand Romney Marsh by Rae (1950), for weanling lambs of the Rambouillet, Columbia, and Targhee breeds by Ercanbrack (1952), for Wisconsin farm flocks by Karam (1953) and Felts (1958), for Navajo crossbred lambs by Sidwell (1954), for Rambouillet rams by Shelton (1959), and for spring lambs by Givens (1960).

Hazel and Terrill (1946) found in using the index they developed for selecting Rambouillet weanling lambs that selection on an index was only slightly more efficient than selection on general appearance for ram lambs where only a small proportion of the lambs were selected. The index was considerably more efficient for ewe lambs where a large proportion of the lambs were selected.

Aside from economic considerations one should appraise the relative heritability of a trait when considering it for use in a selection index. An accurate estimate of heritability is important because the fraction of the gain in selected parents which is transmitted to the offspring is proportional to heritability (Lush, 1935). Thus progress from selection may be relatively rapid for some traits and relatively slow for others even where similar attempts are made to improve them. For this reason respective heritabilities are important in determining how to practice selection for several traits simultaneously.

Traits are often classified on the basis of their relative heritabilities into high, moderate, or low groups. Terrill (1958) in a review article classified the various traits of sheep in such a manner. Traits generally reported to have high heritability include face covering, staple length, skin folds, fiber diameter, and birth coat. Those appearing to be moderately heritable include body weight at birth, weanling and yearling ages, grease and clean fleece weight, clean wool yield, index of overall merit, color of legs, milk production, rate of lambing, and resistance to parasites. Traits with low heritability include type of birth, twinning or multiple births, type or conformation, and condition or fatness.

When two or more traits are being considered for selection a knowledge of the magnitude of genetic and phenotypic correlations is a prime requisite in obtaining maximum efficiency in selection. Only genetic correlations were deemed pertinent to the objectives of this study and for that reason a review of phenotypic correlations has not been included. Genetic correlations indicate the extent to which a primary genetic change in one trait will cause some genetic change in another trait. When the genetic correlation between two traits is positive the simultaneous improvement of the two traits is easier. A negative genetic correlation implies that selection for one trait will by itself cause some deterioration of the other. Basing selection on a properly balanced combination of two negatively correlated traits avoids wide fluctuations in any one of them, but the net effect is that progress will be slower than that which could be achieved if the traits were independent.

Estimates of genetic correlations in sheep reported in the literature are presented in Table 1. Correlations are independent of unit of measure and no difficulty can arise in interpretation where the measure of the trait is quantitative such as pounds for body weight or fleece weight, inches or centimeters for staple length or microns for fiber diameter. Research workers have developed numerous systems of subjective scores for many purposes and used them in many different ways. All scores used by the Western Sheep Breeding Laboratory (1946), Ercanbrack (1952), Karam (1953) and scores for folds used by Morley (1950, 1955), Rae (1950), Bosman (1957) and Shelton (1959) denote decreased merit with larger numerical values. The remainder of the scores used denote increased merit with the higher score.

Crimps per inch is one measure of fiber diameter and count is another commonly used measure. Count is inversely related to fiber diameter. Rae (1950) cited the work of Lang (1947) in which the correlations between count and mean fiber diameter ranged from -0.53 to -0.89 while those between

Table 1. Summary of estimates of genetic correlations reported for sheep

Estimate	Breed	Method and Numbers	Reference
		1. Weaning weight and condition score	
-.14[a]	Rambouillet	Parent-offspring; extensive	W.S.B.L.[b] (1946)
-.51 ± .15	Mixed Whiteface	Parent-offspring; 561 dams, 1156 lambs	Ercanbrack (1952)
		2. Weaning weight and lamb body type score	
-.38[a]	Rambouillet	Parent-offspring; extensive	W.S.B.L. (1946)
-.27 ± .23	Mixed Whiteface	Parent-offspring; 561 dams, 1156 lambs	Ercanbrack (1952)
		3. Weaning weight and pre-weaning rate of gain	
1.08[a]	Farm Flock	Half sib; 25 sires, 498 lambs	Givens (1960)
		4. Total weaning weight and number of lambs reared	
.13[a]	Farm Flock	Parent-offspring; 2602 ewes, 3165 lambs	Felts (1958)
		5. Weaning weight and fold score	
-.14[a]	Rambouillet	Parent-offspring; extensive	W.S.B.L. (1946)

[a]Difference from zero not tested or reported, standard error not computed.

[b]Western Sheep Breeding Laboratory

Table 1. (Continued)

Estimate	Breed	Method and Numbers	Reference
.28 $\pm$ .14	Mixed Whiteface	Parent-offspring; 561 dams, 1156 lambs	Ercanbrack (1952)
		6. Weaning weight and staple length	
-.26[a]	Rambouillet	Parent-offspring; extensive	W.S.B.L. (1946)
-.15 $\pm$ .20	Mixed Whiteface	Parent-offspring; 561 dams, 1156 lambs	Ercanbrack (1952)
-.17[a]	Farm Flock	Half sib; 27 sires, 593 lambs	Karam (1953)
		7. Weaning weight and yearling grease fleece weight	
.23[a]	Farm Flock	Parent-offspring; 2602 ewes, 3165 lambs	Felts (1958)
		8. Weaning weight and face cover score	
-.13[a]	Rambouillet	Parent-offspring extensive	W.S.B.L. (1946)
-.27 $\pm$ .13	Mixed Whiteface	Parent-offspring 561 dams, 1156 lambs	Ercanbrack (1952)
.57[a]	Farm Flock	Half sib; 27 sires, 593 lambs	Karam (1953)
		9. Pre-weaning rate of gain and conformation score	
-.10[a]	Rambouillet	Parent-offspring; 3000 pairs	Shelton (1959)
.39[a]	Farm Flock	Half sib; 25 sires, 498 lambs	Givens (1960)

Table 1. (Continued)

Estimate	Breed	Method and Numbers	Reference
		10. Weaning conformation and staple length	
-.37[a]	Rambouillet	Parent-offspring; extensive	W.S.B.L. (1946)
-.51 ± .16	Mixed Whiteface	Parent-offspring; 561 dams, 1156 lambs	Ercanbrack (1952)
.35[a]	Rambouillet	Sire progeny means; 3000 pairs	Shelton (1959)
		11. Weaning conformation and condition score	
.61[a]	Rambouillet	Parent-offspring; extensive	W.S.B.L. (1946)
.62 ± .17	Mixed Whiteface	Parent-offspring; 561 dams, 1156 lambs	Ercanbrack (1952)
		12. Yearling body weight and clean fleece weight	
-.06[c]	Merino	Parent-offspring; 17 rams, 466 lambs	Morley (1950)
.14[a]	Columbia	Parent-offspring; 761 dam-offspring pairs	Madsen (1958)
.50[a]	Merino	Half sib; 709 d.f.	Bosman (1957)
.65[a]	Merino	Half sib; 854 d.f.	Bosman (1957)
-.12[c]	Merino	Parent-offspring; extensive	Morley (1955)

[c]Reported as not differing from zero at $P < 0.05$, standard error not computed.

Table 1. (Continued)

Estimate	Breed	Method and Numbers	Reference
.24[a]	Merino	Half sib; 100 sires, 740 lambs	Morley (1955)
-.05[a]	Navajo	Parent-offspring; 867 daughter-dam pairs	Hall (1964)
		13. Yearling body weight and grease fleece weight	
-.11[c]	Merino	Parent-offspring; extensive	Morley (1955)
-.03[a]	Merino	Half sib; 100 sires, 740 lambs	Morley (1955)
-.07[a]	Navajo	Parent-offspring 867 daughter-dam pairs	Hall (1964)
		14. Yearling body weight and staple length	
-.26*	Merino	Parent-offspring; extensive	Morley (1955)
-.25[a]	Merino	Half-sib; 100 sires, 740 lambs	Morley (1955)
-.24[a]	Navajo	Parent-offspring 867 daughter-dam pairs	Hall (1964)
		15. Yearling body weight and fiber diameter	
.68[a]	Merino	Half sib; 709 d.f.	Bosman (1957)

*Reported as differing from zero at $P < 0.05$, standard error not computed.

Table 1. (Continued)

Estimate	Breed	Method and Numbers	Reference
.35[a]	Merino	Half sib; 854 d.f.	Bosman (1957)
-.16[a]	Navajo	Parent-offspring; 867 daughter-dam pairs	Hall (1964)
	16. Yearling body weight and % yield		
-.08[c]	Merino	Parent-offspring; extensive	Morley (1955)
.44[a]	Merino	Half sib; 100 sires, 740 lambs	Morley (1955)
	17. Yearling body weight and fold score		
-.34**	Merino	Parent-offspring; extensive	Morley (1955)
-.19[a]	Merino	Half sib; 100 sires, 740 lambs	Morley (1955)
.45	Merino	Half sib; 709 d.f.	Bosman (1957)
.16	Merino	Half sib; 854 d.f.	Bosman (1957)
	18. Yearling body weight and crimps per inch		
.05[c]	Merino	Parent-offspring; extensive	Morley (1955)
-.02[a]	Merino	Half sib; 100 sires, 740 lambs	Morley (1955)

**Reported as differing from zero at $P < 0.01$, standard error not computed.

Table 1. (Continued)

Estimate	Breed	Method and Numbers	Reference
		19. Two year-old body weight and two year-old grease fleece weight	
.43	Columbia	Parent-offspring; 761 pairs	Madsen (1958)
		20. Yearling clean fleece weight and staple length	
-.38[c]	Merino	Parent-offspring; 17 rams, 466 lambs	Morley (1950)
.39**	Merino	Parent-offspring; extensive	Morley (1955)
.32[a]	Merino	Half sib; 100 sires, 740 lambs	Morley (1955)
		20b. Yearling clean fleece weight and straight length	
.50	Merino	Half sib; 709 d.f.	Bosman (1957)
.22	Merino	Half sib; 854 d.f.	Bosman (1957)
		21. Yearling clean fleece weight and fiber diameter	
.03[a]	Merino	Half sib; 709 d.f.	Bosman (1957)
.35[a]	Merino	Half sib; 854 d.f.	Bosman (1957)
		22. Yearling clean fleece weight and crimps per inch	
-.53**	Merino	Parent-offspring; extensive	Morley (1955)
-.35[a]	Merino	Half-sib; 100 sires, 740 lambs	Morley (1955)

Table 1. (Continued)

Estimate	Breed	Method and Numbers	Reference
23. Yearling clean fleece weight and grease fleece weight			
.65**	Merino	Parent-offspring; extensive	Morley (1955)
.76[a]	Merino	Half sib; 100 sires, 740 lambs	Morley (1955)
.26	Columbia	Parent-offspring; 761 daughter-dam pairs	Madsen (1958)
24. Yearling clean fleece weight and % yield			
.56**	Merino	Parent-offspring; extensive	Morley (1955)
.50[a]	Merino	Half sib; 100 sires, 740 lambs	Morley (1955)
.70[a]	Merino	Half sib; 709 d.f.	Bosman (1957)
.10[a]	Merino	Half sib; 854 d.f.	Bosman (1957)
25. Yearling grease fleece weight and staple length			
.25 ± .19	Romney Marsh	Parent-offspring; 628 d.f.	Rae (1950)
-.02[c]	Merino	Parent-offspring; extensive	Morley (1955)
.17[a]	Merino	Half-sib; 100 sires, 740 lambs	Morley (1955)
.20[a]	Columbia	Parent-offspring; 761 daughter-dam pairs	Madsen (1958)

Table 1. (Continued)

Estimate	Breed	Method and Numbers	Reference
26. Yearling grease fleece weight and fleece count			
-.47 ± .19	Romney Marsh	Parent-offspring; 628 d.f.	Rae (1950)
27. Yearling grease fleece weight and % yield			
-.05[c]	Merino	Parent-offspring; extensive	Morley (1955)
-.22[a]	Merino	Half sib; 100 sires, 740 lambs	Morley (1955)
28. Mature grease fleece weight and number of lambs reared			
.39[a]	Farm Flock	Parent-offspring; 2602 ewes, 3165 lambs	Felts (1958)
29. Weaning staple length and face cover score			
.08[a]	Rambouillet	Parent-offspring; extensive	W.S.B.L. (1946)
-.96[a]	Farm Flock	Half sib; 27 sires, 593 lambs	Karam (1953)
-.27 ± .13	Mixed Whiteface	Parent-offspring; 561 dams, 1156 lambs	Ercanbrack (1952)
30. Yearling staple length and crimps per inch			
-.34**	Merino	Parent-offspring; extensive	Morley (1955)
-.66[a]	Merino	Half sib; 100 sires, 740 lambs	Morley (1955)
.19[a]	Merino	Half sib; 709 d.f.	Bosman (1957)

Table 1. (Continued)

Estimate	Breed	Method and Numbers	Reference
-.32[a]	Merino	Half sib; 854 d.f.	Bosman (1957)
		31. Yearling staple length and fiber diameter	
-.42[a]	Merino	Half sib; 709 d.f.	Bosman (1957)
.23[a]	Merino	Half sib; 854 d.f.	Bosman (1957)
		32. Yearling staple length and % yield	
.63**	Merino	Parent-offspring; extensive	Morley (1955)
.27[a]	Merino	Half sib; 100 sire, 740 lambs	Morley (1955)
.64[a]	Merino	Half sib; 709 d.f.	Bosman (1957)
.14[a]	Merino	Half sib; 854 d.f.	Bosman (1957)
		33. Yearling staple length and fleece count	
-.73 ± .16	Romney Marsh	Parent-offspring; 628 d.f.	Rae (1950)
		34. Yearling staple length and two year old grease fleece weight	
.60[a]	Columbia	Parent-offspring; 761 daughter-dam pairs	Madsen (1958)

Table 1. (Continued)

Estimate	Breed	Method and Numbers	Reference
		35. Two year-old staple length and two year-old grease fleece weight	
-.02[a]	Columbia	Parent-offspring; 761 daughter-dam pairs	Madsen (1958)

crimps per inch and mean diameter ranged from -0.70 to -0.92. Sidwell (1954) and Rae (1950) have discussed the use of the count system in evaluating market grade of fleeces when an evaluation for fineness is desired.

Diverse environments were associated with the variety of genetic correlations presented in Table 1. Data used as a basis for the estimates from the Western Sheep Breeding Laboratory (1946), Ercanbrack (1952), Morley (1950), (1955), Madsen (1958) and Hall (1964) were from sheep kept under strictly range conditions where supplemental feeding was absent or kept to a minimum. Data used as a basis in the remainder of the studies came from sheep kept under farm flock conditions or a combination of range and feedlot con ditions. Just how much of the differences in correlations are due to differences in environment cannot be estimated. The evidence that these differences are real is rather convincing.

There appears to be a different relation between body weight and fleece characters under range conditions as compared with the better feed conditions found in farm flocks. The estimates by Bosman (1957) are consistently more positive and of greater magnitude than those of Morley (1955). Different strains of Merinos are involved as well as different environments. Different goals of selection may have caused different gene frequencies in the two groups, but a more likely explanation is that the genes that affect body weight and those that affect fleece characters act differently in the two environments. Morley (1950) and Rae (1950, 1956) have reviewed possible reasons for negative estimates of genetic correlations between fleece traits, namely fleece weight and count or fiber diameter, but made no serious attempt to interpret these differences or to suggest causes for differential gene action in different environments.

The estimates of correlations by the Western Sheep Breeding Laboratory (1946) and Ercanbrack (1952) between weaning weight and traits that were evaluated subjectively agreed rather closely and indicated that in these flocks merit in body type, condition, and face cover would increase with an increase in weaning weight. One exception to this general pattern of agreement is that of weaning weight and fold score. Ercanbrack (1952) noted this difference and attributed the difference to sampling error. The estimate of 0.57 reported by Karam (1953) for the correlation between weaning weight and face cover is opposite in sign and of greater magnitude than the other corresponding estimates. Karam noted this and used the estimates reported by the Western Sheep Breeding Laboratory in constructing a selection index for ewes.

Increasing merit in conformation score is genetically correlated with weaning weight and condition score in range sheep and indicates that an increase in weight will contribute to merit in both condition and conformation. Condition and conformation are primary factors that contribute to market grade of lambs.

The estimate (1.08) by Givens (1960) between weaning weight and pre-weaning rate of gain was interpreted by him as meaning that pre-weaning rate of gain could be substituted for weaning weight. This could be particularly useful where lambs were weaned at widely differing ages or when exact ages were not known.

The two estimates of 0.50 and 0.65 reported by Bosman (1957) are accepted as incomplete evidence that body weight contributes positively to fleece weight under farm flock or feedlot conditions. Under range conditions the four estimates concerned with the same two traits are evenly divided as to sign and would seem to indicate that the true relationship under range conditions is probably zero or slightly negative. The same reasoning will probably be true of body weight and grease fleece weight, in view of the high positive correlations reported by Morley (1955) between grease fleece weight and clean fleece weight.

The estimates of Bosman (1957) and Morley (1955) provide some basis for thinking that the relation between body weight and fiber diameter is either zero or positive. The estimates of Bosman (1957) indicate a strong relationship under feedlot conditions while those of Morley (1955) between body weight and crimps per inch indicate that the relation is practically zero under range conditions for Merinos.

The estimates of Morley (1955) and Bosman (1957) clearly indicated that fleece weight is positively correlated genetically with fiber diameter under either range or farm flock conditions. This genetic antagonism was emphasized by Morley (1955) as indicating that the rate of improvement in fleece weight could be reduced by 30% whenever crimps per inch were also selected. Producers in Australia have established an excellent reputation in the world wool market for quality of product and show more concern for fineness than do producers in the United States.

Staple length appears to be associated positively with fiber diameter. According to Rae (1950), this association appears to be particularly strong in the Romney Marsh where an estimate of -0.73 was obtained between yearling staple length and fleece count.

Felts (1958) estimated the genetic correlation between grease fleece weight and the number of lambs reared as 0.39.

Should this estimate reflect the true parameter much would be gained by selecting for grease fleece weight in terms of an increased number of lambs reared.

Since all traits considered in a selection index do not have equal economic importance the relative value of the traits must be considered. The procedure usually followed has been to indicate the relative increase in dollars and cents that can be expected from a unit improvement in each trait. Winters, et al. (1946) were among the first to report on relative economic values. They estimated that the average price per pound for the four top blood grades of wool at Boston was 3.4 times that per pound of lamb at South St. Paul during the period 1930-38.

Some of the estimates of relative economic values used in constructing selection indexes for sheep are presented in Table 2. Morley (1950) and the Western Sheep Breeding Laboratory (1946) used centimeters as the unit of measure for staple length but Shelton (1959) used inches as his unit. Pounds were the basic units used to measure traits concerned with weight in all reports. For traits scored on a subjective basis the Western Sheep Breeding Laboratory (1946) used a scoring system from 1 through 5 with the higher score denoting less merit. Shelton (1959) reported scoring face cover and body conformation from 1 through 4 with the higher score as being more abundant, thus a low score for face cover was more desirable. A high score for type was more desirable

Table 2. Relative economic values of traits considered in the construction of selection indexes

Trait	Workers				
	W.S.B.L.[a] (1946)	Morley (1950)	Felts (1958)	Shelton (1959)	Givens (1960)
Weaning weight	1.00	1.00	1.00	1.00	1.00
Type	-4.20			0.56	
Condition	-4.20				
Market grade					13.63
Staple length	15.36	1.00		3.88	
Face cover	-12.86			-2.93	
Folds	-6.70	-5.00		-0.01	
Fiber diameter		2.00			
Clean fleece weight		10.00		5.77	
Grease fleece weight			3.90		
Number of lambs born			66.90		

[a]Western Sheep Breeding Laboratory

and higher values represented more folds. The values presented in Table 2 are all relative to weaning weight within each worker's report. For example, Western Sheep Breeding Laboratory (1946) reported an economic value of $.112 per pound of weaning weight and $1.72 per centimeter increase in staple length. The value of 15.36 was obtained by dividing $1.72 by $.112.

The most notable feature of Table 2 is the variety of traits that have been included in these indexes and the wide range of relative economic values that workers attached to the traits. The index of the Western Sheep Breeding Laboratory was developed for use in selecting range Rambouillet lambs. Morley's index was for Merino yearling ewes in Australia. Shelton's index was constructed for use in evaluating Rambouillet rams at the end of performance tests in Texas. Farm flock ewe evaluation was the object of Felt's index. The index developed by Givens has been recommended for use in Virginia and similar areas for the selection of spring ewe lambs.

With the exception of Winters, et al. (1946) all reports on selection indexes reviewed for this study reported using the simplifying assumption that genetic improvement was possible without adding to the fixed cost or feed cost of a sheep enterprise. Winters, et al. (1946) compared various systems for rating ewes on their productivity. The index they accepted as most practicable was based on gross return of the relative value of wool and lamb referred to earlier. Another index included the gross return from wool and lamb production as well as an adjustment for maintenance requirements of the ewe and lamb. This index was considered the most accurate, but it was criticized because of the difficulty involved in its computation and interpretation.

Lindholm and Stonaker (1957) computed net income for 118 individual Hereford steers by 19 sires and studied the multiple correlation between traits and net income per steer. They used the standard partial regression coefficient of the traits on net income as the estimates of the relative importance of the traits.

Stevens, et al. (1961) divided the profit records of southwestern Wyoming sheep enterprises into a high earning group and a low earning group on the basis of profit per head. They then compared the 10% with the highest earnings with the 10% that had the lowest earnings. The more profitable group had a gross income per head of $15.57 compared with $10.87 for the group with the lowest earnings. They attributed the extra income of the more profitable group to a 13.6% difference in lamb crop, a 3.2% lower death loss of ewes, 0.9% lower lamb mortality, 5.1 pounds heavier lambs at weaning, 0.4 pounds more wool and an 8.8 cents per pound advantage in the price of wool. The most profitable group also had $2.46 less cost per head of which $1.20 was due to less labor. These differences reflect environmental, managerial and to some extent genetic differences between flocks, but specific data were not available to assess these differences.

In an economic study of sheep production in southwestern Utah, Broadbent (1946) concluded that on many ranches the total earnings could be increased more economically by increasing the efficiency and productivity of the enterprise than by increasing the numerical size of the operation.

Gray (1961) compared northern and southern New Mexico sheep operations with respect to the production factors of lamb crop, death loss, fleece weight and lamb weights for the 1957-59 period. He reported a one pound difference in fleece weight and 4.4 pounds difference in lamb weight with the heavier weights coming from the southern area. The net cash income per head was $3.88 in the northern area and $7.10 in the southern area. Gray considered the environment in northern New Mexico to be the more favorable, particularly for lamb production, and suggested that northern producers investigate improved management practices and selection programs.

The application of the production function approach to production problems in agriculture was outlined by Heady (1952) and described in detail by Heady and Dillon (1961). Principles described in these two publications are applicable to most production problems in agriculture where profit maximization and optimum ranges of inputs and outputs are desired.

Strain (1961) studied the influence of changes in egg production, adult body weight, and price on profit potentials of broiler enterprises. He used different levels of genetic correlations between traits and found that favorable or unfavorable correlated responses would influence maximum profit potential and optimum levels of egg production of parent flocks. Changes in broiler price and feed price merely raised or lowered the level of profit potential. Strain emphasized that the primary interest in his study was not profit *per se* but the relative changes in profit that were due to changes in production factors which had economic importance in a broiler selection program.

PROFIT EQUATIONS FOR SHEEP ENTERPRISES

The use of the production function approach to production problems in agriculture described by Heady (1952) has been widely accepted in agricultural economics and appears to be ideally suited as a method for investigating the objectives of this study. A complete study of the production functions and related aspects necessary to Heady's type of approach was beyond the scope of this study.

Strain (1961) has suggested a more direct approach to production problems concerned with both genetic and economic relations. Strain used profit potential equations in his investigation of genetic and economic relations in the broiler industry. The approach suggested by Strain was used as a guide in developing the profit potential equations in this study.

Profit potential equations specify all the income and cost factors pertinent to an enterprise together with the links between income and cost factors. The links between income and cost factors are supplied by the genetic correlations and the specification of income factors in terms of factors contributing to cost.

The use of genetic correlations was preferred to phenotypic correlations because genetic correlations may have a different effect on the profit potential of an enterprise, particularly in the case of a positive phenotypic correlation and a corresponding negative genetic correlation. It was assumed in this study that replacement rams and replacement ewes are to be selected from within the flock. No serious error is introduced if all or part of the replacement stock is purchased from other flocks at prices comparable to those the home-raised stock can be sold for.

Definitions and Symbolism

Two broad divisions of sheep enterprises are recognized within the sheep industry. Range sheep enterprises are found in the western United States where the sheep subsist primarily on native grasses and shrubs. The operator is usually dependent on sheep for his primary source of income although it is not unusual for a rancher to maintain both cattle and sheep. In the intermountain states, range sheep are normally herded in bands of 800 to 2,000 head depending on the season of the year. In Texas and southern New Mexico the sheep forage for themselves without herding in fenced pastures.

Farm flock sheep enterprises are found in the irrigated valleys in the western United States and in the farming areas of the Midwest, East and Southeast. The owner of the farm flock sheep enterprise is usually not dependent on the farm flock for his main source of income. The farm flock will contribute varying proportions of total income depending on its size relative to the size of the entire farm operation.

Notation for and definition of factors involved in sheep production

Π_{ij} = profit potential of the ith type of an enterprise with the $_j$th selection goal

R = general notation for revenue

R_1 = mutton income

R_2 = wool income

R_3 = lamb income

R_4 = incentive income

E = general notation for cost

E_1 = ewe feed cost

E_2 = replacement feed cost

E_3 = cost of supplemental feed for a farm flock lamb

X_1 = pounds of cull ewe sold per breeding ewe

X_2 = pounds of clean wool sold per breeding ewe in the range enterprise or pounds of grease wool in the farm flock enterprise

X_3 = pounds of milk-fat lamb per breeding ewe

X_4 = pounds of feeder lamb per breeding ewe

P_1 = per pound price of salvage ewes

P_2 = per pound price of wool on a clean basis in range enterprise

P_3 = per pound price of milk-fat lamb

P_4 = per pound price of feeder lamb

P_5 = per pound price of ewe feed

P_6 = per pound price of lamb supplemental feed

P_7 = difference of the nationwide average selling price of wool, grease basis and the incentive level

P_8 = per pound price of wool, grease basis, farm flock

C_1 = number of ewes in the breeding flock

C_2 = number of cull ewes per year

C_3 = number of ewes needed for replacement purposes per year

C_4 = number of ewes dead annually

C_5 = rate of replacement of breeding flock = C_3/C_1

C_6 = fractional mortality of ewes = C_4/C_1

C_7 = number of ewes of the ith age expressed as a fraction of C_1, $i = 0, 1, 2, \ldots .8$ where 0 represents the weaning age, 1 the yearling age, etc.

C_8 = marketing charges per grease pound of wool in a range enterprise

C_9 = fraction of ewes lambing

C_{11} = fraction of lambs which live from birth to weaning
= 1 - fraction of mortality in suckling lambs

C_{12} = market weight of milk-fat lambs

C_{13} = Y intercept, annual feed requirement of a ewe

C_{14} = increase in feed consumption as a result of gestation

C_{15} = increase in feed consumption as a result of pregnancy and milk production for one lamb

C_{16} = increase in feed consumption due to milk production for second member of a twin pair.

C_{17} = Y intercept, total feed requirement of a replacement ewe lamb

C_{18} = fractional mortality of replacement ewe lambs

C_{19} = amount of supplemental feed per twin lamb marketed in a farm flock enterprise

C_{20} = amount of feed per single lamb marketed in a farm flock enterprise

C_{--} = fixed cost associated with a breeder ewe

Z_1 = total pounds of cull ewe marketed

Z_2 = average market weight of cull ewes

Z_3 = fractional yield of clean wool in the fleece

Z_4 = average annual clean fleece weight of range mature ewes

Z_5 = average lambing rate of breeder ewes

Z_6 = fraction of fat lambs among all lambs marketed

$1 - Z_6$ = fraction of feeder lambs among all lambs marketed

Z_7 = annual feed consumption of a breeder ewe

Z_8 = average body weight of breeder ewes

Z_{81} = average body weight of yearling ewes

Z_9 = total feed consumption of a replacement ewe from weaning to first breeding

Z_{10} = average weaning weight, all lambs

Z_{11} = weaning weight of replacement ewe lambs

Z_{12} = weaning weight of feeder lambs

Z_{13} = average fiber diameter of the fleece for mature ewes

Z_{131} = average fiber diameter of the fleece for yearling ewes

Z_{14} = staple length of the fleece for the mature ewes

Z_{141} = staple length of the fleece for yearling ewes

Z_{15} = number of ewe lambs saved for replacement expressed as a fraction of the total number of lambs weaned

Z_{16} = number of twin lambs born expressed as a fraction of lambs born

$1 - Z_{16}$ = number of single lambs born expressed as a fraction of lambs born

Z_{17} = condition score

Z_{18} = average annual grease fleece weight of farm flock mature ewes

Z_{181} = average annual grease fleece weight of farm flock yearling ewes

Z_{19} = fractional rate of incentive payment

β_1 = regression of annual feed consumption for maintenance of a breeder ewe on body weight

β_2 = partial regression of total feed consumption of replacement on weaning weight

β_3 = partial regression of total feed consumption of replacements on squared initial weight

Other factors

r_{ij} = genetic correlation between the ith and jth traits

A(r) = a vector of correlation coefficients

A(P) = a vector of prices

s_{--} = the genetic standard deviation of the trait in question

Derivation

The net profit from a sheep enterprise is influenced by many factors. Figure 1 is a representation of the factors entering into ewe cost, lamb cost, replacement costs, and revenue. The breeding flock influences lamb costs directly while revenue is influenced by wool and salvage ewe income as well as lamb income. Interest centers on the profit per ewe maintained in the breeding flock. Since the main interest in this study is the genetic effects on net returns, fixed costs including labor, building and equipment depreciation and interest on investment in buildings, equipment and live-stock are considered as constants.

Range sheep enterprise marketing both milk-fat lambs and feedlot finished lambs

π_{1-} represents the profit potential of a ewe in this type of an operation as a function of gross income and total costs (E). Thus,

$$\pi_{1-} = R - E.$$

The effect of various production factors on profit potential

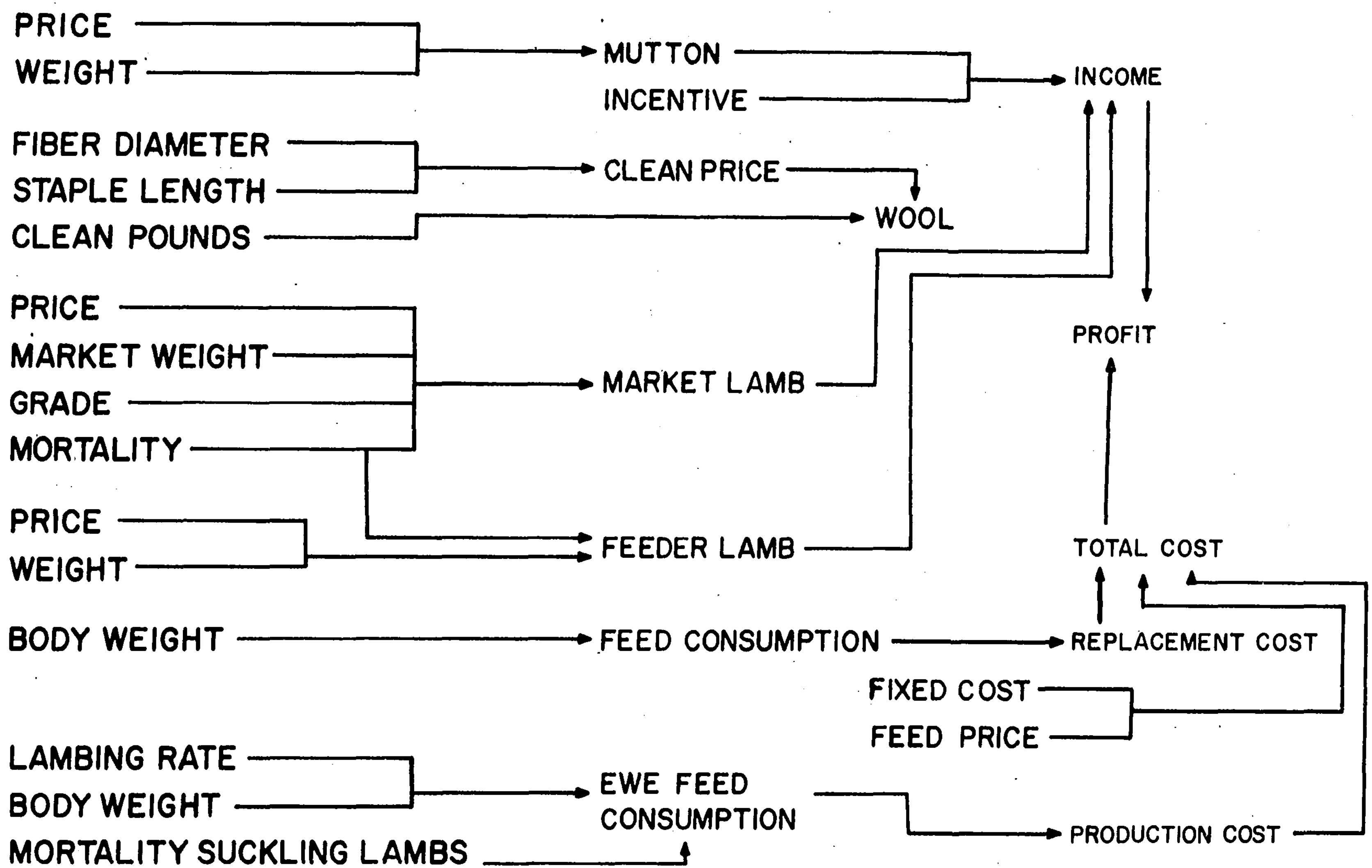

Figure 1. Factors influencing profit potential in a sheep enterprise

is of primary interest in this study, rather than profit potential *per se*.

It is necessary to express revenue and total costs in terms of relevant production factors. Revenue is a function of income from the sale of cull ewes, wool, lambs and incentive payments and can be expressed as:

$$R = R_1 + R_2 + R_3 + R_4,$$

where

$$R_1 = X_1 P_1,$$

in which

$$\begin{aligned} X_1 &= Z_1/C_1 \\ &= Z_2 (C_2/C_1) \\ &= Z_2 (C_3 - C_4)/C_1 \\ &= Z_2 (C_5 - C_6); \end{aligned}$$

$$R_2 = X_2 (P_2 - C_8/Z_3)$$

in which

$$X_2 = (1 - C_6/2) Z_4 + C_5 (1 - C_{18}/2) Z_{41};$$

$$R_3 = X_3 P_3 + X_4 P_4,$$

in which

$$X_3 = Z_6 (C_{11} C_9 Z_5 - C_5) C_{12}$$

and

$$X_4 = (1 - Z_6) (C_{11} C_9 Z_5 - C_5) Z_{12};$$

$$\begin{aligned} R_4 = {} & [1/Z_3] [Z_4 (1 - C_6/2) + C_5 Z_{41} (1 - C_{18}/2)] \\ & [P_2 Z_3 - C_8] Z_{19} + (4P_7/100) (X_3 + X_4). \end{aligned}$$

The total cost associated with one ewe in the breeding flock is the sum of the ewe feed cost, the replacement feed cost, and the fixed cost associated with a breeder ewe. Thus,

$$E = E_1 + E_2 + C_{--},$$

where

$$E_1 = Z_7 P_5,$$

in which

$$Z_7 = (1 - C_6/2)(C_{13} + \beta_1 Z_8) + (1 - C_6/4) C_{14} + C_9 C_{15} + (Z_5 - C_9) C_{16}$$

and

$$E_2 = C_5 (1 - C_{18}/2)(Z_9 P_5)$$

in which

$$Z_9 = C_{17} + \beta_2 Z_{11} - \beta_3 Z_{11}^2.$$

The ewe feed cost, E_1, is a function of body weight, conception rate, lambing rate and price of ewe feed. Changes in each of the factors will account for differences in feed consumption between flocks. This approach does not allow for ewe differences in efficiency of conversion of feed to lamb and wool or for decreased feed consumption of a ewe due to the loss of her lamb or lambs. The replacement cost, E_2, reflects the average cost of raising replacement ewe lambs. The replacement cost was computed on an annual cost basis, and this necessitated allowing for the average productive life of a ewe. The average productive life of the ewe was reflected in the replacement rate.

The profit potential of a breeder ewe in a range sheep enterprise producing both milk-fat and feeder lambs can then be described as

$$
\begin{aligned}
\pi_{1-} = {} & [Z_2\ (C_5 - C_6)]\ P_1 \\
& +[(1 - C_6/2)\ Z_4 + C_5\ (1 - C_{18}/2)\ Z_{41}][P_2 - C_8/Z_3] \\
& +[Z_6\ (C_{11}\ C_9\ Z_5 - C_5)\ C_{12}]\ P_3 \\
& +[(1 - Z_6)\ (C_{11}\ C_9\ Z_5 - C_5)\ Z_{12}]\ P_4 \\
& +[1/Z_3][Z_4\ (1 - C_6/2) + C_5\ Z_{41}\ (1 - C_{18}/2)] \\
& \quad [P_2\ Z_3 - C_8]\ Z_{19} \\
& +[4P_7/100][(C_{11}\ C_9\ Z_5 - C_5)][Z_6\ (C_{12} - Z_{12}) + Z_{12}] \\
& -[(1 - C_6/2)\ (C_{13} + \beta_1\ Z_8) + (1 - C_6/4)\ C_{14} \\
& \quad + C_9\ C_{15} + (Z_5 - C_9)\ C_{16}]\ P_5 \\
& - C_5\ [1 - C_{18}/2][(C_{17} + \beta_2\ Z_{11} - \beta_3\ Z_{11}{}^2)\ P_5] \\
& - C_{--}.
\end{aligned}
$$

π_{1-} can be used to estimate the profit potential of a ewe in a range enterprise as a function of costs involved, and the income from wool and lamb.

Range sheep enterprises producing only feeder lambs

Range sheep enterprises that produce only feeder lambs usually have lower production costs than those producing both milk-fat and feeder lambs. Smaller ewes with finer fleeces are usually found in the environment normally associated with low precipitation and poorer pasture conditions best suited for feeder lamb production.

The derivation of the profit potential equation for a breeder ewe in a feeder lamb enterprise followed the same pattern as that used to develop π_{1-}. Consequently, π_{2-} is presented without comment except to note that the only difference between the two equations is that π_{2-} contains no provision for milk-fat lambs.

$$\begin{aligned}\pi_{2-} = {} & [Z_2 (C_5 - C_6)] P_1 \\ & +[(1 - C_6/2) Z_4 + C_5 (1 - C_{18}/2)][P_2 - C_8/Z_3] \\ & +[(C_{11} C_9 Z_5 - C_5) Z_{12}] P_4 \\ & +[1/Z_3][Z_4 (1 - C_6/2) + C_5 Z_{41} (1 - C_{18}/2)] \\ & \quad [P_2 Z_3 - C_8] Z_{19} \\ & +[4P_7/100][(C_{11} C_9 Z_5 - C_5) Z_{12}] \\ & -[(1 - C_6/2) (C_{13} + \beta_1 Z_8) + (1 - C_6/4) C_{14} \\ & \quad + C_9 C_{15} + (Z_5 - C_9) C_{16}] P_5 \\ & - C_5 [1 - C_{18}/2][(C_{17} + \beta_2 Z_{11} - \beta_3 Z_{11}^2) P_5] \\ & - C_{--}.\end{aligned}$$

Farm flock sheep enterprise marketing milk-fat lambs

Farm flocks have been considered apart from range flocks because of the different environment and management associated with the intensive type of agriculture common to farm areas. Marketing of farm flock lambs usually occurs earlier than that of the bulk of the range lambs of a comparable grade and weight. The derivation of the profit potential equation for a breeder ewe in a farm flock enterprise differed little from preceding derivations. Consequently, π_{3-} which specifies the profit potential of a farm flock breeder ewe has been presented without comment.

$$\pi_{3-} = [Z_2\ (C_5 - C_6)]\ P_1$$
$$+[(1 - C_6/2)\ Z_{18} + C_5\ (1 - C_{18}/2)\ Z_{41}]\ P_8$$
$$+[(C_{11}\ C_9\ Z_5 - C_5)\ C_{12}]\ P_3$$
$$+[4P_7/100][(C_{11}\ C_9\ Z_5 - C_5)]$$
$$-[(1 - C_6/2)\ (C_{13} + \beta_1\ Z_8) + (1 - C_6/4)\ C_{14}$$
$$+ C_9\ C_{15} + (Z_5 - C_9)\ C_{16}]\ P_5$$
$$- C_5\ [1 - C_{18}/2][(C_{17} + \beta_2\ Z_{11} - \beta_3\ Z_{11}^2)\ P_5]$$
$$- C_{11}\ Z_{16}\ C_{19}\ P_6 - C_{11}\ (1 - Z_{16})\ C_{20}\ P_6 - C_{--}$$

where

$$Z_{16} = 2(Z_5 - C_9)/Z_5.$$

It was assumed in this study that lambs from farm flocks were marketed as milk-fat lambs of an acceptable grade and weight. This assumption omits the possibility of feeder lambs being sold as a product of the farm flock. Lamb mortality was assumed independent of lambing rate in this study. Provision for supplemental feeding, more commonly referred to as creep feeding of lambs, has been made by use of the factors, C_{18}, C_{19}, and Z_{16} to allow for this commonly used management practice.

THE EFFECT OF CHANGES IN PERFORMANCE ON PROFIT POTENTIAL

Profit potential may respond to changes in performance in a complex manner, including the effects of both the direct change in the primary trait and the correlated changes which may occur in other traits.

The flock owner producing lambs is interested not only in the performance of the lambs but also in the performance of the parent flock. He needs to know what effect a genetic change in breeding flock performance will have on lamb performance and its ultimate effect on net income. A genetic change in breeding flock performance influences net income in two ways. Ewe production costs and income can be influenced through the direct change in the trait. Other traits affecting gross income and costs of production may change due to correlated responses induced by the change in the primary trait. When selection is directed toward one trait, there is not only a genetic change in that trait, but also changes in other traits genetically correlated with the trait under selection. A genetic change due to a correlated response may be favorable or unfavorable depending on the sign of the genetic correlation.

Range Sheep Enterprise Marketing Milk-fat and Feeder Lambs

In order to evaluate the effect of a genetic change in a trait for a range sheep enterprise equation π_{1-} may be used.

If selection is directed solely toward wool production in yearling ewes, and if correlated responses exist in other traits then Π_{1-} becomes

$$\begin{aligned}\Pi_{11} = {} & [(Z_2 + \Delta Z_2)\ (C_5 - C_6)]\ P_1 \\ & + [(1 - C_6/2)\ (Z_4 + \Delta Z_4) + C_5\ (1 - C_{18}/2) \\ & \quad (Z_{41} + \Delta Z_{41})]\ [P_2 - C_8\ (Z_3 + \Delta Z_3)] \\ & + \Big[[Z_6 + \Delta Z_6]\ [C_{11}\ C_9\ (Z_5 + \Delta Z_5) - C_5]\ C_{12}\Big]\ P_3 \\ & + \Big[[1 - Z_6 - \Delta Z_6]\ [C_{11}\ C_9\ (Z_5 + \Delta Z_5) - C_5] \\ & \quad [Z_{12} + \Delta Z_{12}]\Big]\ P_4 + [1/(Z_3 + \Delta Z_3)] \\ & \quad [(Z_4 + \Delta Z_4)\ (1 - C_6/2) + C_5\ (Z_{41} + \Delta Z_{41}) \\ & \quad (1 - C_{18}/2)]\ [P_2\ (Z_3 + \Delta Z_3) - C_8]\ Z_{19} \\ & + [4P_7/100]\ [C_{11}\ C_9\ (Z_5 + \Delta Z_5) - C_5] \\ & \quad \Big[[Z_6 + \Delta Z_6]\ [C_{12} - Z_{12} - \Delta Z_{12}] + Z_{12} + \Delta Z_{12}\Big] \\ & - \Big[[1 - C_6/2]\ [C_{13} + \beta_1\ (Z_8 + \Delta Z_8)] + [1 - C_6/4] \\ & \quad C_{14} + C_9\ C_{15} + [Z_5 + \Delta Z_5 - C_9]\ C_{16}\Big]\ P_5 \\ & - C_5\ [1 - C_{18}/2]\ [C_{17} + \beta_2\ (Z_{11} + \Delta Z_{11}) - \beta_3 \\ & \quad (Z_{11} + \Delta Z_{11})^2]\ P_5 - C\text{--},\end{aligned}$$

where ΔZ_4 and ΔZ_{41} are the direct changes in clean wool production and ΔZ_2, ΔZ_3, ΔZ_5, ΔZ_6, ΔZ_8, ΔZ_{11}, ΔZ_{12}, ΔZ_{13}, and ΔZ_{14} are the correlated genetic responses. A similar equation results when selection is directed to some other trait such as weaning weight.

To compute the profit potential for a change in a trait, correlated responses must be estimated. Direct estimates from the regression of trait j on trait i are not completely satisfactory because they include the effects of temporary environmental factors. In this study the regressions were computed from estimates of genetic correlations and genetic variances of the respective traits. Given the genetic correlation and variance components for traits i and j the regression is:

$$b_{ij} = r_{ij}\, s_i/s_j,$$

where r_{ij} represents the genetic correlation between the traits being considered. In some cases the correlated response is obvious, e.g., a change in yearling clean fleece weight will produce a change in yearling body weight if the genetic correlation is not zero. In other cases the correlated response is not as obvious. In this study where correlated responses did not appear to be straight forward, genetic correlations between intervening traits were used to compute the correlated response expected.

In the following sections only the subscripts of the input factors or traits have been used to identify regression coefficients computed from the corresponding genetic correlations, e.g., $b_{8:81}$ identifies the regression of mature body weight per unit change in yearling body weight. A similar system of notation was adopted for identifying genetic correlations.

The total response expected in the dependent variable, i.e. the correlated response, (ΔZ_{--}), was computed as follows when yearling clean fleece weight was changed in a range sheep enterprise producing both milk-fat and feeder lambs:

$$\Delta Z_4 = b_{4:41}\ \Delta Z_{41}$$
$$= r_{4:41}\ (s_4/s_{41})\ \Delta Z_{41},$$
$$\Delta Z_{13} = [b_{131:41}\ \Delta Z_{41}]\ [b_{13:131}]$$
$$= [r_{131:41}\ (s_{131}/s_{41})\ \Delta Z_{41}]$$
$$[r_{13:131}\ (s_{13}/s_{131})],$$
$$\Delta Z_{14} = [b_{141:41}\ \Delta Z_{41}]\ [b_{14:141}]$$
$$= [r_{141:41}\ (s_{141}/s_{41})\ \Delta Z_{41}]$$
$$[r_{14:141}\ (s_{14}/s_{141})],$$
$$\Delta Z_8 = [b_{81:41}\ \Delta Z_{41}]\ [b_{8:81}]$$
$$= [r_{81:41}\ (s_{81}/s_{41})\ \Delta Z_{41}]$$
$$[r_{8:81}\ (s_8/s_{81})],$$
$$\Delta Z_{81} = b_{81:41}\ \Delta Z_{41}$$
$$= r_{81:41}\ (s_{81}/s_{41})\ \Delta Z_{41},$$
$$\Delta Z_2 = \Delta Z_8,$$
$$\Delta Z_3 = [b_{31:41}\ \Delta Z_{41}]\ [b_{3:31}]$$
$$= [r_{31:41}\ (s_{31}/s_{41})\ \Delta Z_{41}]$$
$$[r_{3:31}\ (s_3/s_{31})],$$
$$\Delta Z_5 = b_{5:8}\ \Delta Z_8$$
$$= r_{5:8}\ (s_5/s_8)\ \Delta Z_8,$$
$$\Delta Z_{10} = b_{10:81}\ \Delta Z_8$$
$$= [r_{10:81}\ (s_{10}/s_{81})\ \Delta Z_{41}],$$
$$\Delta Z_6 = b_{6:10}\ \Delta Z_{10}$$
$$= .2b_{17:10}\ \Delta Z_{10}$$
$$= .2r_{17:10}\ (s_{17}/s_{10})\ \Delta Z_{10},$$
$$\Delta Z_{11} = \Delta Z_{12} = \Delta Z_{10}.$$

In the preceding derivation the assumption was made that an increase in market weight of cull ewes would correspond exactly with an increase in mature body weight. While this assumption may not exactly reflect actual conditions it does not appear to be in serious error. A constant rate of conception over all ages has been implied, which is not completely true because young ewes tend to have slightly lower conception rates than older ewes. Provision has not been made for reduction in income from ram lambs that would be retained for future use as sires, however, the effect on overall profit was expected to be small, particularly when surplus rams can be disposed of as sale rams to other producers.

It was assumed that the average increase in weaning weight would apply to the weights of both replacement and feeder lambs. This assumption is not completely realistic in that a pronounced change in lambing rate, or percentage of milk-fat lambs produced will affect the weight of the feeder lambs. A positive change in lambing rate would lower the average weaning weight and probably increase the proportion of feeder lambs produced unless additional expense in improving management were incurred. An increase in the proportion of fat lambs produced would have the effect of lowering the proportion of feeder lambs, but increase the weight of the feeder lambs. However, the assumption was considered to be a reasonable one within the limits of change considered in this study.

The correlated response in fiber diameter (Z_{13}) and staple length (Z_{14}) contribute indirectly to income through a qualitative change which may be reflected in the per pound selling price of the wool.

The correlated responses when average weaning weight (Z_{10}) was changed for computation of profit potential, π_{12}, in a range enterprise were computed as follows:

$$\Delta Z_{11} = \Delta Z_{12} = \Delta Z_{10},$$

$$\begin{aligned}
\Delta Z_6 &= b_{6:10}\ \Delta Z_{10} \\
&= .2b_{17:10}\ \Delta Z_{10} \\
&= .2r_{17:10}\ (s_{17}/s_{10})\ \Delta Z_{10},
\end{aligned}$$

$$\begin{aligned}
\Delta Z_{81} &= b_{81:10}\ \Delta Z_{10} \\
&= r_{81:10}\ (s_{81}/s_{10})\ \Delta Z_{10},
\end{aligned}$$

$$\begin{aligned}
\Delta Z_8 &= b_{8:10}\ \Delta Z_{10} \\
&= r_{8:10}\ (s_8/s_{81})\ \Delta Z_{10},
\end{aligned}$$

$$\begin{aligned}
\Delta Z_{41} &= b_{41:81}\ \Delta Z_{81} \\
&= r_{41:81}\ (s_{41}/s_{81})\ \Delta Z_{81},
\end{aligned}$$

$$\begin{aligned}
\Delta Z_4 &= b_{4:41}\ \Delta Z_{41} \\
&= r_{4:41}\ (s_4/s_{41})\ \Delta Z_{41},
\end{aligned}$$

$$\begin{aligned}
\Delta Z_{131} &= b_{131:41}\ \Delta Z_{41} \\
&= r_{131:41}\ (s_{131}/s_{41})\ \Delta Z_{41},
\end{aligned}$$

$$\begin{aligned}
\Delta Z_{13} &= b_{13:131}\ \Delta Z_{131} \\
&= r_{13:131}\ \Delta Z_{131},
\end{aligned}$$

$$\begin{aligned}
\Delta Z_5 &= b_{5:8}\ \Delta Z_8 \\
&= r_{5:8}\ (s_5/s_8)\ \Delta Z_8,
\end{aligned}$$

$$\Delta Z_2 = \Delta Z_8,$$

$$\Delta Z_3 = b_{3:4}\,\Delta Z_4$$

$$= r_{3:4}\,(s_3/s_4)\,\Delta Z_4,$$

$$\Delta Z_{141} = b_{141:10}\,\Delta Z_{10}$$

$$= r_{141:10}\,(s_{141}/s_{10})\,\Delta Z_{10},$$

$$\Delta Z_{14} = b_{14:141}\,\Delta Z_{141}$$

$$= r_{14:141}\,(s_{14}/s_{141})\,\Delta Z_{141}.$$

Range Sheep Enterprise Marketing All Lambs as Feeders

π_{2-} may be used to evaluate the effect of a genetic change in a trait for a range flock producing only feeder lambs. If selection is directed toward wool production in yearling ewes, (Z_{41}), and if correlated responses exist in other traits then $_{2-}$ becomes

$$\begin{aligned}
\pi_{21} = {} & [(Z_2 + \Delta Z_2)\ (C_5 - C_6)]\ P_1 \\
& + [(1 - C_6/2)\ (Z_4 + \Delta Z_4) + C_5\ (1 - C_{18}/2) \\
& \quad (Z_{41} + \Delta Z_{41})]\ [P_2 - C_8/(Z_3 + \Delta Z_3)] \\
& + \Big[[C_{11}\ C_9\ (Z_5 + \Delta Z_5) - C_5]\ [Z_{12} + \Delta Z_{12}]\Big]\ P_4 \\
& + \Big[[1/(Z_3 + \Delta Z_3)]\ [(Z_4 + \Delta Z_4)\ (1 - C_6/2) + C_5 \\
& \quad (Z_{41} + \Delta Z_{41})\ (1 - C_{18}/2)] \\
& \quad [P_2\ (Z_3 + \Delta Z_3) - C_8]\Big]\ Z_{19} + [4P_7/100] \\
& \quad \Big[[C_{11}\ C_9\ (Z_5 + \Delta Z_5) - C_5]\ [Z_{12} + \Delta Z_{12}]\Big] \\
& - \Big[[1 - C_6/2]\ [C_{13} + \beta_1\ (Z_8 + \Delta Z_8)] + [1 - C_6/4] \\
& \quad C_{14} + C_9\ C_{15} + [Z_5 - C_9]\ C_{16}\Big]\ P_5 - C_5 \\
& \quad [1 - C_{18}/2]\ [C_{17} + \beta_2\ (Z_{11} + \Delta Z_{11}) - \beta_3 \\
& \quad (Z_{11} + \Delta Z_{11})^2]\ P_5 - C_{--}.
\end{aligned}$$

The correlated responses due to changes in traits in a feeder lamb range enterprise were derived similarly to those outlined previously. The correlated responses were computed as follows when yearling clean fleece weight was the primary goal of selection:

$$\Delta Z_4 = b_{4:41}\ \Delta Z_{41}$$
$$= r_{4:41}\ (s_4/s_{41})\ \Delta Z_{41},$$
$$\Delta Z_{13} = [b_{131:41}\ \Delta Z_{41}]\ [b_{13:131}]$$
$$= [r_{131:41}\ (s_{131}/s_{41})\ \Delta Z_{41}]$$
$$[r_{13:131}\ (s_{13}/s_{131})],$$
$$\Delta Z_{14} = [b_{141:41}\ \Delta Z_{41}]\ [b_{14:141}]$$
$$= [r_{141:41}\ (s_{141}/s_{41})\ \Delta Z_{41}]$$
$$[r_{14:141}\ (s_{14}/s_{141})],$$
$$\Delta Z_8 = [b_{81:41}\ \Delta Z_{41}]\ [b_{8:81}]$$
$$= [r_{81:41}\ (s_{81}/s_{41})\ \Delta Z_{41}]$$
$$[r_{8:81}\ (s_8/s_{81})],$$
$$\Delta Z_2 = \Delta Z_8,$$
$$\Delta Z_3 = [b_{31:41}\ \Delta Z_{41}]\ [b_{3:31}]$$
$$= [r_{31:41}\ (s_{31}/s_{41})\ \Delta Z_{41}]$$
$$[r_{3:31}\ (s_3/s_{31})],$$
$$\Delta Z_5 = b_{5:8}\ \Delta Z_8$$
$$= r_{5:8}\ (s_5/s_8)\ \Delta Z_8,$$
$$\Delta Z_{10} = b_{10:81}\ \Delta Z_{41}$$
$$= r_{10:81}\ (s_{10}/s_{81})\ \Delta Z_8],$$
$$\Delta Z_{11} = \Delta Z_{12} = \Delta Z_{10}.$$

The correlated responses were computed as follows for the profit potential, π_{22}, of the feeder lamb enterprise when weaning weight was changed.

$$
\begin{aligned}
\Delta Z_{11} &= \Delta Z_{12} = \Delta Z_{10}, \\
\Delta Z_{81} &= b_{81:10}\ \Delta Z_{10} \\
&= r_{81:10}\ (s_{81}/s_{10})\ \Delta Z_{10}, \\
\Delta Z_{8} &= b_{8:10}\ \Delta Z_{81} \\
&= r_{8:10}\ (s_{8}/s_{81})\ \Delta Z_{81}, \\
\Delta Z_{41} &= b_{41:81}\ \Delta Z_{81} \\
&= r_{41:81}\ (s_{41}/s_{81})\ \Delta Z_{81}, \\
\Delta Z_{4} &= b_{4:41}\ \Delta Z_{41} \\
&= r_{4:41}\ (s_{4}/s_{41})\ \Delta Z_{41}, \\
\Delta Z_{131} &= b_{131:41}\ \Delta Z_{41} \\
&= r_{131:41}\ (s_{131}/s_{41})\ \Delta Z_{41}, \\
\Delta Z_{13} &= b_{13:131}\ \Delta Z_{131} \\
&= r_{13:131}\ \Delta Z_{131}, \\
\Delta Z_{141} &= b_{141:10}\ \Delta Z_{10} \\
&= r_{141:10}\ (s_{141}/s_{10})\ \Delta Z_{10}, \\
\Delta Z_{14} &= b_{14:141}\ \Delta Z_{141} \\
&= r_{14:141}\ (s_{14}/s_{141})\ \Delta Z_{141}, \\
\Delta Z_{5} &= b_{5:8}\ \Delta Z_{8} \\
&= r_{5:8}\ (s_{5}/s_{8})\ \Delta Z_{8}, \\
\Delta Z_{2} &= \Delta Z_{8}, \\
\Delta Z_{3} &= b_{3:4}\ \Delta Z_{4} \\
&= r_{3:4}\ (s_{3}/s_{4})\ \Delta Z_{4}.
\end{aligned}
$$

Farm Flock Enterprise Marketing All Lambs as Milk-fat

In order to evaluate the effect of a genetic change in a trait for a farm flock sheep enterprise π_{3-} may be used. If selection is directed toward wool production in yearling ewes and if correlated responses exist in other traits then π_{3-} becomes

$$\begin{aligned}\pi_{31} = {} & [(Z_2 + \Delta Z_2)\ (C_5 - C_6)]\ P_1 \\ & + [(1 - C_6/2)\ (Z_{18} + \Delta Z_{18}) + C_5\ (1 - C_{18}/2) \\ & \quad (Z_{181} + \Delta Z_{181})]\ P_8 \\ & + [C_{11}\ C_9\ (Z_5 + \Delta Z_5) - C_5]\ C_{12}\ P_3 + [4P_7/100] \\ & \quad [C_{11}\ C_9\ (Z_5 + \Delta Z_5) - C_5]\ C_{12} - \Big[[1 - C_6/2] \\ & \quad [C_{13} + \beta_1\ (Z_8 + \Delta Z_8)] + [1 - C_6/4]\ C_{14} + C_9\ C_{15} \\ & + [Z_5 + \Delta Z_5 - C_9]\ C_{16}\Big]\ P_5 - C_5\ [1 - C_{18}/2] \\ & \quad [C_{17} + \beta_2\ C_{12} - B_3\ C_{12}^{\ 2}]\ P_5 - C_{11}\ (Z_{16} + \Delta Z_{16}) \\ & \quad C_{19}\ P_6 - C_{11}\ (1 - Z_{16})\ C_{20}\ P_6 - C_{--}\end{aligned}$$

where ΔZ_4 and ΔZ_{41} are the direct changes in wool production and ΔZ_2, ΔZ_5, ΔZ_8, ΔZ_{16} are the possible correlated genetic responses. A similar equation may be obtained when selection is directed to some other trait such as weaning weight.

The correlated responses due to changes in traits in the farm flock were derived similarly to those derived for range enterprises. The assumptions involved were essentially the same except that a correlated response in weaning weight would not be expected as all lambs are marketed on practically a weight constant basis, and any gain or loss realized from selection would be reflected in earlier or later marketing dates.

The correlated responses visualized in a farm flock when yearling grease fleece weight (Z_{181}) is changed are as follows:

$$\Delta Z_{18} = b_{18:181}\ \Delta Z_{181}$$
$$= r_{18:181}\ (s_4/s_{41})\ \Delta Z_{181},$$
$$\Delta Z_{81} = b_{81:181}\ \Delta Z_{181}$$
$$= r_{81:181}\ (s_{81}/s_{41})\ \Delta Z_{41},$$
$$\Delta Z_8 = b_{8:81}\ \Delta Z_{81}$$
$$= r_{8:81}\ (s_8/s_{81})\ \Delta Z_{81},$$
$$\Delta Z_2 = \Delta Z_8,$$
$$\Delta Z_5 = b_{5:18}\ \Delta Z_{18}$$
$$= r_{5:18}\ (s_5/s_{18})\ \Delta Z_{18},$$
$$\Delta Z_{16} = [2(Z_5 + \Delta Z_5 - C_9)]\ [1/Z_5 + \Delta Z_5)] - Z_{16}.$$

The correlated responses visualized in a farm flock when lambing rate (Z_5) is changed to allow for computation of π_{32} are as follows:

$$\Delta Z_8 = b_{8:5}\ \Delta Z_5$$
$$= r_{8:5}\ (s_8/s_1)\ \Delta Z_5,$$
$$\Delta Z_2 = \Delta Z_8,$$
$$\Delta Z_{18} = b_{18:5}\ \Delta Z_5$$
$$= r_{18:5}\ (s_{18}/s_5)\ \Delta Z_5,$$
$$\Delta Z_{181} = b_{181:18}\ \Delta Z_{18}$$
$$= r_{181:18}\ (s_{181}/s_{18})\ \Delta Z_{18},$$
$$\Delta Z_{16} = [2(Z_5 + \Delta Z_5 - C_9)]\ [1/(Z_5 + \Delta Z_5)] - Z_{16}.$$

NUMERICAL VALUES AND PROCEDURES USED IN EVALUATING PROFIT POTENTIALS

Complete data on an individual ranch or farm basis for a study of this type were not available. Most of the genetic information required was available from research stations but the cost data were not appropriate because the cost structure associated with a research unit differs quite markedly from that of a commercial unit. Consequently, the specification of profit in terms of inputs and outputs peculiar to individual operations could not be accomplished. The most logical numerical estimates for the various factors, both constant and variable, were compiled from the literature and the author's personal experience.

The numerical values used for the factors that were considered as constant within an enterprise have been presented in Table 3. The effect of subsidy payments to sheepmen in the form of incentive payments could not be ignored in describing the profit structure of a sheep enterprise. Provision for considering incentive payments was directly allowed for in profit potential equations of range sheep enterprises and, as will be described later, in farm flock enterprises. Immasche (1954) has described the incentive payment program for wool in detail. An incentive level is established by the U. S. Secretary of Agriculture for the marketing year. Since the beginning of the incentive payment program in 1955 this level has been set at 62 cents

Table 3. Numerical values used for constant factors in range and farm flock enterprises

Factor	Range	Farm
C_5	0.20	0.20
C_6	0.07	0.10
C_8	$ 0.06	----
C_9	0.90	0.90
C_{11}	0.90	0.85
C_{12}	92.5 lbs.	92.5 lbs.
C_{13}	219.0 lbs.	219.0 lbs.
C_{14}	52.0 lbs.	52.0 lbs.
C_{15}	242.0 lbs.	242.0 lbs.
C_{16}	92.0 lbs.	92.0 lbs.
C_{17}	945.0 lbs.	945.0 lbs.
C_{18}	0.08	0.08
C_{19}	----	180.0 lbs.
C_{20}	----	147.0 lbs.
C_{--}	$ 9.00	$ 4.00

per grease pound of wool. At the conclusion of the marketing year in December the average price received by farmers for grease wool in the United States is calculated. The incentive level minus the national average is termed the difference (P_7). This difference is divided by the national average to determine the per cent rate of incentive payment (Z_{19}). This rate is then applied to the per pound selling price that the producer receives for his wool, grease basis, to determine the rate of payment per grease pound. Credit for wool on lambs is computed directly from the difference.

No information was available in the literature to assess differences in feed cost for ewes of differing body weights or levels of production. In range areas stocking rates are calculated on a per head basis regardless of the weight or productive level of the breeder ewes involved. This approach was not suitable for use in this study because there was no way to attempt to assess differences in costs due to different ewe weights or productive levels. For this reason the analysis described in the following paragraphs was used to attempt an assessment of the differences in costs due to different ewe weights or productive levels.

Pope, _et_ _al_. (1957) have set forth the nutritive requirements for the various classes of sheep to promote optimum growth, production, and prevention of nutritional deficiency. The daily feed requirements for ewes of 100 to 160 pounds for maintenance were projected to an annual total and a prediction equation was developed from a simple regression computation in which body weight (Z_8) was the independent variable and annual feed consumption the dependent variable. The added feed requirement for gestation (C_{14}) was 52 pounds with a range of 44 to 58 pounds and was determined by averaging the requirements for gestation for each body weight. The total feed requirement for milk production for one lamb (C_{15}) was 242 pounds with a range of 220 to 264 pounds and was calculated in a manner similar to that for the requirement for gestation.

The added feed requirement of the ewe for milk production for the second member of a twin pair (C_{16}) was 92 pounds with a range of 81 to 101 pounds. The reason for the difference between the two feed requirements is that a ewe will only produce about one-third more milk when nursing twins than when nursing singles.

The resulting prediction equation for the average annual feed requirement of a ewe ($\hat{Y}$) nursing twins was:

$$\begin{aligned}\hat{Y} &= C_{13} + \beta_1 Z_8 + C_{14} + C_{15} + C_{16} \\ &= 219.0 + (7.30)\ Z_8 + 52.0 + 242.0 + 92.0.\end{aligned}$$

When the preceding prediction equation is combined with the necessary production factors for predicting the feed consumption of a breeder ewe (Z_7) the following prediction equation results:

$$\begin{aligned}Z_7 &= (1 - C_6/2)\ (C_{13} + \beta_1 Z_8) + (1 - C_6/4)\ (C_{14}) \\ &\quad + C_9\ C_{15} + (Z_5 - C_9)\ C_{16} \\ &= [1 - C_6/2]\ [219.0 + (7.30)\ Z_8] \\ &\quad + (1 - C_6/4)\ (52.0) \\ &\quad + C_9\ (242.0) + (Z_5 - .90)\ C_{16}.\end{aligned}$$

The recommendations of Pope, _et al_. (1957) were also used as a basis for estimating the total feed consumption of replacement ewe lambs. Requirements for daily feed consumption were projected to a total feed requirement for 14 months and a curvilinear regression analysis completed. From this regression analysis the prediction equation,

$$Z_9 = C_{17} + \beta_2 Z_{11} + \beta_3 Z_{11}^2$$
$$= 945 + (9.090) Z_{11} - (.041) Z_{11}^2,$$

was obtained. Here Z_9 is the predicted total feed consumption for 14 months for a replacement ewe lamb with an initial weight of Z_{11}.

Necessary to the computation of the profit potential in farm flocks were estimates of the amount of supplemental feed consumed by twin lambs and single lambs. The best available estimates were those of Wickersham[1] (1961) who reported that the amount of supplemental feed consumed per twin lamb marketed (C_{19}) was 180 pounds while that consumed per single lamb marketed was 147 pounds.

Wankier[2] (1961) described production costs for 1959 and 1960 for range sheep enterprises. Costs figures for Colorado and Idaho were used to estimate the annual feed cost and the annual fixed cost of a breeder ewe in a range sheep enterprise marketing both milk-fat and feeder lambs. All costs

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[1]Wickersham, T. Iowa State University of Science and Technology, Ames, Iowa. Data from demonstration flock. Private communication. 1961.

[2]Wankier, F. T. 414 Crandall Building, Salt Lake City 1, Utah. Cost squeeze tightens on sheep industry. Private communication. 1961.

other than feed purchased, grazing fees, and a charge for land use were included in fixed costs. The annual total cost associated with a range ewe in these two states was $25.45. Of this total cost, $13.75, was apportioned to fixed cost

(C__) and $11.70 to feed cost.

The feed consumption of a 140 pound ewe in a flock producing a 140% lamb crop would be 1563 pounds as determined from the feed prediction equations described earlier. To this must be added the proportionate share of feed of the ewes eventual replacement. Four to five years is the average productive life of a range ewe and a replacement ewe lamb with a weaning weight of 84 pounds will consume 1545 pounds of feed in 14 months. One-fourth of 1545 pounds was added to 1563 pounds to obtain a total feed figure of 1949 pounds. To obtain a per pound feed cost $11.70 was divided by 1949 pounds for an estimate of 0.6 cents which was used in the range enterprise producing milk-fat and feeder lambs. A similar procedure was followed in estimating feed costs used in this study for other types of enterprises.

The production cost figures described by Stevens, et al. (1961) and quoted by Wankier[1] (1961) were used to arrive at an estimate for fixed cost and feed cost for a range enterprise marketing feeder lambs only. The annual total cost associated with a range ewe in Wyoming was $17.94. Of this total cost, $13.83, was apportioned to fixed cost and $4.11 to feed cost. The estimated cost of a pound of range feed in this type of range enterprise was 0.25 cents. The estimates of fixed cost for the two types of range enterprises differed

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[1]Wankier, op. cit.

very little. For ease in computation and to avoid negative values for profit potential evaluations as much as possible a fixed cost of $9.00 per breeder ewe was used in this study. As was pointed out earlier, the main interest in this study was changes in profit potentials and not in the profit of the sheep enterprises *per se*.

The difference between the two estimates of feed costs was quite large. This difference was partially accounted for by the fact that range enterprises producing milk-fat lambs usually feed more supplemental feed in the winter, lamb the ewes earlier, and during lambing feed hay and grain quite extensively. Better grazing conditions are usually associated with the milk-fat lamb type of production, but at a higher cost than the grazing conditions associated with an operation producing feeder lambs only.

Letters of inquiry were sent to the extension animal husbandmen of the midwestern farm states requesting information on the cost of production for a farm flock ewe. The reported average annual fixed cost associated with a farm flock ewe was $3.53 and the average annual feed cost was $11.14. From the average annual feed cost the per pound price of feed for a farm flock ewe was estimated as 0.75 cents. The annual fixed cost was set at $4.00 for a farm flock ewe.

Price information for feed cost and lamb and salvage ewe prices are presented in Table 4. The medium prices for

Table 4. Prices of lamb, slaughter ewes, and feed involved in profit potential equations of sheep enterprises (cents per pound)

Factor	Price level		
	High	Medium	Low
Salvage ewes (P_1):			
Range	5.0	4.2	3.5
Farm	6.0	5.2	4.5
Milk-fat lambs (P_3):			
Range	24.0	20.8	17.0
Farm	25.0	21.8	18.0
Feeder lambs (P_4):	22.5	19.3	16.0
Ewe feed (P_5):			
Range (M and F)	0.7	0.6	----
Range (F)	0.3	0.25	----
Farm	0.9	0.75	----
Lamb supplemental feed (P_6)	4.0	3.5	----

range lambs and salvage ewes were computed from the average price received on the Omaha market for the marketing season for 1958, 1959, and 1960 from statistics compiled by the U. S. Agricultural Marketing Service (1958, 1959 and 1960a).

The average prices of slaughter lambs and slaughter ewes on the Chicago market for the same years were used to determine the average prices appropriate for farm flock enterprises. Average prices for sheep and wool have varied little from the 1958-60 averages.

Measurement and price information for wool are given in Table 5. Prices were computed from averages compiled by the U. S. Agricultural Marketing Service (1960b) for the period 1958-60. Prices quoted for territory graded wools were used as a price basis for range wools. In the evaluation of the profit potential equation, measurements of the factors of staple length and fiber diameter were used to predict the appropriate price of wool. For example, if the calculation for $Z_{13} + \Delta Z_{13}$ equalled 23.6μ and $Z_{14} + \Delta Z_{14}$ as 3.25" in the price used per pound of clean wool, the value of P_2 would have been $1.13. Calculations for fiber diameter and staple length were considered apart from the general profit equations.

In order to evaluate the profit potential equations for two levels of wool prices within each type of range enterprise, wool income was calculated on the basis of (1) average price with no income from the incentive payment program to represent a low level of wool prices and, (2) income from the incentive payment program to represent wool income under government support or wool income on a high level of wool prices. The factor (Z_{19}), the percent rate of incentive payment, was assigned the values of 0 or 46.2% to accomplish this purpose. In farm flock enterprises two values for the price of wool (P_8) were used to evaluate profit potentials

Table 5. Measurement and price information on wool

Type	Fiber diameter (μ)	Staple length (in.)	Price (cents per lb.)
Range (P_2):			
Fine:	17.7--22.0		
strictly staple		2.75 & up	122
good French combing		2.00--2.75	115
average French combing		1.50--2.00	108
One-half blood	22.1--24.9		
strictly staple		3.00 & up	113
good French combing		2.50--3.00	110
average French combing		1.50--2.50	108
Three-eighth's blood	25.0--27.8		
strictly staple		3.25 & up	109
average French combing		2.25--3.25	99
One-quarter blood	27.9--30.9		
strictly staple		3.50 & up	105
French		2.50--3.50	95
Low one-quarter blood	31.0--34.3		
strictly staple		4.00 & up	96
clothing		4.00 & down	91
Farm:			
Average price received by farmers, United States (P_8)			42.4
Difference: Incentive level minus national average (P_7)			19.6

for a high level and a low level of wool income. These values were the national average price of 42.4 cents per grease pound and the incentive level of 62.0 cents per grease pound.

Income from lambs and salvage ewes was calculated for three levels within each type of enterprise with the restriction that a low level of lamb and salvage ewe income did not occur with a high level of wool income. Lamb and wool prices tend to vary together, and high wool prices are seldom associated with low lamb prices or low wool prices associated with high lamb prices. Two levels of cost of feed were used for all enterprises. The total number of combinations within an enterprise due to price levels alone was eight and all price combinations used have been presented in Table 6.

The means and genic standard deviations of factors contributing to the correlated responses are given in Table 7. The genetic correlations together with the corresponding regression coefficients necessary for predicting correlated responses are presented in Table 8. All genetic correlations between the same trait measured at the yearling age and the mature age have been taken as .8, as most evidence indicates that the same genes which influence a particular trait early in life will to a large extent exert a similar influence at later periods. The genetic correlation between weaning weight and mature body weight was taken as .4. These values are approximations only and it is not the intent of the

Table 6. Combinations of price levels used within each type of enterprise

Wool	Lamb and salvage ewe	Feed cost
High	High	High
		Medium
	Medium	High
		Medium
Low	Medium	High
		Medium
	Low	High
		Medium

author to imply that there is sufficient evidence to be certain these values are valid estimates of the true parameters in question.

The genetic correlation between body weight and fleece weight is of primary interest in this study. Bosman (1957) reported a pronounced positive relation between these traits in his study. Morley (1955) reported both a positive and negative relation between the two traits. For this reason three levels of the genetic correlation between the two traits were chosen to place limits on the values obtained for profit potentials in range enterprises. As no estimates

Table 7. Means and genic standard deviations of factors contributing to correlated responses

Factor	Unit of measure	Mean: Range: Milk-fat and feeder	Mean: Range: Feeder	Mean: Farm	Standard deviation
Z_2	lb.	135.0	120.0	145.0	----
Z_3	----	0.46	40.0	----	.032
Z_{31}	----	0.46	40.0	----	.032
Z_4	lb.	5.0	4.5	----	0.5
Z_{41}	lb.	4.25	3.75	----	0.42
Z_5	lamb	1.3	1.0	1.4	0.14
Z_6	----	0.40	----	----	----
Z_8	lb.	140.0	125.0	145.0	7.0
Z_{81}	lb.	120.0	110.0	130.0	4.9
Z_{10}	lb.	80.0	70.0	92.5	4.7
Z_{11}	lb.	84.0	75.0	92.5	4.7
Z_{12}	lb.	74.0	70.0	----	----
Z_{13}	μ	23.0	21.0	----	0.5
Z_{131}	μ	23.0	21.0	----	0.5
Z_{14}	in.	2.9	2.4	----	0.3
Z_{141}	in.	2.9	2.4	----	0.3
Z_{17}	arbitrary	----	----	----	0.2
Z_{18}	lb.	----	----	10.0	0.6
Z_{181}	lb.	----	----	9.0	0.5

Table 8. Genetic correlations and corresponding values for regression coefficients used to estimate correlated responses in range sheep enterprises

Genetic correlation		Regression coefficient	
Description	Estimate	Description	Estimate
$r_{3:31}$	0.80	$b_{3:31}$	0.800
$r_{3:4}$	0.50	$b_{3:4}$	0.032
$r_{31:41}$	0.50	$b_{31:41}$	0.950
$r_{5:8}$	0	$b_{5:8}$	0
	0.10	$b_{5:8}$	0.002
$r_{81:41}$	-.25	$b_{81:41}$	-2.900
	-.25	$b_{41:81}$	-.021
	0	$b_{81:41}$	0
	0	$b_{41:81}$	0
	0.25	$b_{81:41}$	2.900
	0.25	$b_{41:81}$	0.021
$r_{8:81}$	0.80	$b_{8:81}$	1.140
$r_{81:10}$	0.50	$b_{81:10}$	0.520
		$b_{10:81}$	0.480
$r_{10:8}$	0.40	$b_{10:8}$	0.270
		$b_{8:10}$	0.596
$r_{131:41}$	0.35	$b_{131:41}$	0.420
$r_{13:131}$	0.80	$b_{13:131}$	0.800
$r_{141:41}$	0	$b_{141:41}$	0
	0.30	$b_{141:41}$	0.210

Table 8. (Continued)

Genetic correlation		Regression coefficient	
Description	Estimate	Description	Estimate
$r_{141:10}$	0	$b_{141:10}$	0
	0.20	$b_{141:10}$	0.013
$r_{14:141}$	0.80	$b_{14:141}$	0.800
$r_{17:10}$	0.35	$b_{17:10}$	0.015

between grease fleece weight (Z_{18}) and body weight (Z_8) were available in the literature the values of 0 and .5 were used as estimates of this genetic correlation in evaluating farm flock profit potentials.

Felts (1958) reported an estimate of .39 for the genetic correlation between the number of lambs weaned by a ewe and fleece weight. This estimate was considerably higher than one would expect. Consequently, two levels of this correlation were used. The genetic correlation between lambing rate (Z_5) and body weight (Z_8) was not thought to be high. Nevertheless the two traits could be associated, particularly in range flocks, in view of the findings of Terrill and Stoehr (1942) who reported increased lamb production with increased body weight of range ewes.

Numerical values used for genetic correlations and the corresponding regression coefficients necessary for computing correlated responses have been presented in Table 8 and Table 9.

Table 9. Genetic correlations and corresponding values for regression coefficients used to estimate correlated responses in farm flock enterprises

Genetic correlation		Regression coefficient	
Description	Estimate	Description	Estimate
$r_{5:8}$	0	$b_{5:8}$	0
	0	$b_{8:5}$	0
	0.10	$b_{5:8}$	0.002
	0.10	$b_{8:5}$	5.000
$r_{8:81}$	0.80	$b_{8:81}$	1.140
$r_{81:181}$	0	$b_{81:181}$	0
	0.50	$b_{81:181}$	4.900
$r_{18:5}$	0	$b_{18:5}$	0
		$b_{5:18}$	0
	0.25	$b_{18:5}$	1.070
		$b_{5:18}$	0.058
$r_{18:181}$	0.80	$b_{18:181}$	0.960
		$b_{181:18}$	0.670

The means of factors given in Table 7 were used to calculate the profit potential of a group of sheep with corresponding performance characteristics. The resulting profit potentials were then computed for each change in clean wool production by intervals of .45 pounds and by intervals of 2.75 pounds for weaning weight for range sheep enterprises. For farm flock enterprises the resulting profit potentials were computed for each change in number of lambs born (Z_5) by .05 lamb or increments of 5% in lambing rate and by intervals of .50 pound for each change in grease fleece weight production (Z_{18}).

The intervals referred to can be thought of as genetic gain that might be possible in one generation where selection would be directed to the particular trait in question. These intervals reflect heritabilities and selection differentials that one might find actually in use in flock improvement today. These intervals do not cover the same number of standard deviations for each trait and in this respect the profit potentials obtained when yearling clean fleece weight was increased covered a wider range than when weaning weight was changed.

A price vector, a(P), was introduced to simplify the description of price combinations used. For example, the price vector (M, W, F) = (M, H, M) means that the medium level of prices for lamb and salvage ewe income, the high level of prices for wool income, and the medium level of prices for feed cost were used. For the correlation vector, a(r), only the genetic correlations that were assigned two or more values need to be considered. For example, the correlation vector $(r_{5:81}, r_{81:41}, r_{141:41}) = (.1, 0, .3)$ means that the profit potential was evaluated using $r_{5:8} = .1$, $r_{81:41} = 0$, and $r_{141:41} = .3$.

An illustration using the foregoing information is presented to show the method of computing profit potential in a range enterprise marketing both milk-fat and feeder lambs.

The performance characteristics given in Table 7 are introduced into π_{1-} to obtain profit,

$$
\begin{aligned}
\pi_{1-} = {} & [135 (.20 - .07)]\ .042 + [(.965)\ (5.00) \\
& \quad + (.20)\ (.96)\ (4.25)]\ [1.10 - .06/.46] \\
& + \left[.40\ [(.90)^2\ (1.30 - .20]\ 92.50\right]\ .208 \\
& + \left[.60\ [(.90)^2\ (1.30) - .20]\ 74.0\right]\ .193 \\
& + [1/.46]\ [(5.00)\ (.965) + (.20)\ (4.25)\ (.96)] \\
& \quad [(1.10)\ (.46) - .06]\ [.462] \\
& + [(4)\ (.196)/100]\ [(.90)^2\ (1.30) - .20] \\
& \quad [(.40)\ (92.5 - 74.0) + 74.0] \\
& - \Big[[.965]\ [219 + (7.30)\ (140)] + (.9825)\ (52) \\
& \quad + (.90)\ (242) + (1.3 - .9)\ (92)\Big]\ .006 \\
& - .20\ [.96]\ [945 + (9.09)\ (84) - (.041)\ (84)^2] \\
& \quad [.006] - 9.00 \\
= {} & .737 + 5.469 + 6.564 + 7.309 + 2.526 + .544 \\
& -9.019 - 1.634 - 9.00 \\
= {} & \$3.497 \text{ per breeder ewe.}
\end{aligned}
$$

The values, .737, 5.469, 6.564, 7.309, 2.526, .544, 9.019, 1.634, and 9.00 represent salvage ewe income, wool income, milk-fat lamb income, feeder lamb income, incentive payment income, ewe expense, replacement expense and fixed cost respectively when prices are (M, W, F) = (M, H, M).

To illustrate the computations showing the influence of genetic correlations in a range enterprise marketing milk-fat and feeder lambs π_{11} may be used. Assume that selection has effectively increased yearling clean fleece weight by .45 pounds with price levels the same as in the preceding example, and $a(r) = (r_{5:8}, r_{81:41}, r_{141:41}) = (.1, .25, .3)$.

Then,

$$\begin{aligned}
\pi_{11} = {} & [(135 + 1.496)\ (.20 - .07)]\ .042 \\
& + [(.965)\ (5.00 + .428) + (.20)\ (.96) \\
& \quad (4.25 + .45)]\ [1.10 - .06/(.46 + .014)] \\
& + \Big[[.40 + .002]\ [(.90)^2\ (1.30 + .003) - .20] \\
& \quad [92.5]\Big]\ .208 + \Big[[1 - .40 - .002] \\
& \quad [(.90)^2\ (1.30 + .003) - .20]\ [74 + .216]\Big]\ .193 \\
& + [1/(.46 + .014)] \\
& \quad [(5.428)\ (.965) + (.20)\ (4.25 + .45)\ (.96)] \\
& \quad [(1.10)\ (.46 + .014) - .06]\ .462 \\
& + [(4)\ (.196)/100]\ [(.90)^2\ (1.30 + .003) - .20] \\
& \quad \Big[[.40 + .002]\ [92.5 - 74.0 - .216] \\
& \quad + 74.0 + .216\Big] \\
& - \Big[[.965]\ [219 + 7.30\ (140 + 1.496)] + (.9825) \\
& \quad (52) + (.90)\ (242) + (1.30 + .003 - .9)\ (92)\Big]
\end{aligned}$$

$$[.006]$$
$$- .20\ [.96]\ [945 + (9.09)\ (84 + .216)$$
$$- .041\ (84 + .216)^2]\ \ [.006]\ \ - 9.00$$
$$= .745 + 5.976 + 6.613 + 7.370 + 2.761 + .548$$
$$- 9.084 - 1.636 - 9.00$$
$$= \$4.294 \text{ per breeder ewe.}$$

Thus, an increase in clean fleece weight of the yearling ewes would increase the profit potential from $3.50 to $4.29 per breeder ewe under the conditions assumed.

Procedures similar to the foregoing were used to compute profit potentials for all enterprises considered in this study. All computations were made on an IBM 1620 computer to eight significant digits, and all results were quantified as dollars per breeding ewe.

RESULTS AND DISCUSSION

Importance of Yearling Clean Fleece Weight in Range Enterprises

Wool income, salvage ewe and lamb income, and ewe and replacement feed cost for various combinations of prices, genetic correlations and levels of wool production for range sheep enterprises are presented in Appendix Tables 22 through 27.

Profit potentials per breeding ewe in range enterprises have been presented in Tables 10 and 11 for different levels of yearling clean fleece weight production. For zero correlations, i.e., a(r) = (0, 0, 0) profit potential increases in direct proportion to an increase in fleece weight with the rate of increase dependent on the price of wool. When a(r) = $(r_{5:8}, r_{81:41}, r_{141:41})$ = (0, -.25, 0) profit potential slightly decreases over a(r) = (0, 0, 0) because the predicted correlated response decreases the salvage ewe and lamb income more than it decreases the feed cost. When a(r) = (0, .25, 0) salvage ewe and lamb income increased at a faster rate than the increase in feed cost and a higher rate of change in the profit potential was noted when compared with a(r) = (0, 0, 0). When a(r) = (.1, .25, 0) profit potential was higher than when a(r) = (0, .25, 0) because the correlated response was to increase lambing rate and subsequently income from lamb.

When profit potentials from a(r) = (0, 0, 0) and a(r) =

Table 10. Influence of yearling clean fleece weight on profit potential (π_{11}) for different combinations of relationships in a range sheep enterprise producing milk-fat and feeder lambs

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Ylg. clean fleece weight (lbs.)								
4.25	4.084	5.859	1.721	3.497	-1.349	.426	-3.921	-2.145
	$a(r_{5:8}, r_{81:41}, r_{141:41}) = a(r)$							
	$a(r) = (0, -.25, 0)$							
4.70	4.807	6.572	2.458	4.223	-.844	.920	-3.402	-1.637
5.15	5.534	7.289	3.198	4.952	-.337	1.416	-2.881	-1.127
5.60	6.264	8.008	3.941	5.684	.171	1.914	-2.359	-.615
6.05	6.997	8.729	4.686	6.418	.682	2.414	-1.834	-.102
6.50	7.731	9.453	5.433	7.155	1.194	2.916	-1.308	.412
	$a(r) = (0, -.25, .3)$							
4.70	4.807	6.572	2.458	4.223	-.844	.920	-3.402	-1.637
5.15	5.826	7.580	3.489	5.243	-.138	1.616	-2.682	-.928
5.60	6.577	8.321	4.254	5.997	.385	2.129	-2.145	-.401
6.05	7.332	9.064	5.021	6.753	.911	2.643	-1.605	.126
6.50	8.088	9.810	5.790	7.512	1.438	3.160	-1.064	.657

Table 10. (Continued

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Ylg. clean fleece weight (lbs.)								
	$a(r) = (0, 0, 0)$							
4.70	4.825	6.601	2.463	4.239	-.841	.933	-3.413	-1.638
5.15	5.571	7.347	3.209	4.984	-.332	1.433	-2.904	-1.128
5.60	6.319	8.095	3.957	5.733	.179	1.955	-2.392	-.616
6.05	7.071	8.847	4.709	6.484	.693	2.469	-1.878	-.102
6.50	7.825	9.601	5.463	7.239	1.209	2.985	-1.362	.413
	$a(r) = (0, 0, .3)$							
4.70	4.825	6.601	2.463	4.239	-.841	.933	-3.413	-1.638
5.15	5.862	7.638	3.500	5.276	-.132	1.642	-2.704	-.929
5.60	6.633	8.408	4.270	6.046	.394	2.169	-2.177	-.402
6.05	7.406	9.182	5.044	6.819	.923	2.698	-1.648	.126
6.50	8.182	9.958	5.820	7.596	1.453	3.229	-1.118	.657
	$a(r) = (0, .25, 0)$							
4.70	4.843	6.630	2.468	4.255	-.839	.946	-3.425	-1.638
5.15	5.606	7.403	3.218	5.015	-.328	1.469	-2.927	-1.129
5.60	6.371	8.179	3.971	5.779	.185	1.993	-2.427	-.619
6.05	7.139	8.958	4.726	6.545	.700	2.519	-1.925	-.106
6.50	7.909	9.739	5.484	7.313	1.217	3.046	-1.422	.407

Table 10. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Ylg. clean fleece weight (lbs.)								
				a(r) = (0, .25, .3)				
4.70	4.843	6.630	2.468	4.255	-.839	.946	-3.425	-1.638
5.15	5.897	7.694	3.509	5.306	-.129	1.668	-2.728	-.930
5.60	6.684	8.492	4.284	6.092	.399	2.207	-2.213	-.405
6.05	7.474	9.293	5.061	6.880	.929	2.748	-1.696	.122
6.50	8.266	10.096	5.841	7.670	1.461	3.290	-1.178	.651
				a(r) = (.1, -.25, 0)				
4.70	4.762	6.527	2.419	4.184	-.882	.882	-3.433	-1.668
5.15	5.444	7.198	3.120	4.874	-.412	1.341	-2.942	-1.189
5.60	6.129	7.872	3.824	5.567	.060	1.802	-2.450	-.707
6.05	6.818	8.549	4.532	6.263	.534	2.265	-1.955	-.223
6.50	7.509	9.229	5.242	6.962	1.010	2.730	-1.458	.261
				a(r) = (.1, -.25, .3)				
4.70	4.762	6.527	2.419	4.184	-.882	.882	-3.433	-1.668
5.15	5.735	7.489	3.411	5.165	-.212	1.540	-2.743	-.990
5.60	6.442	8.185	4.137	5.880	.274	2.016	-2.235	-.493
6.05	7.153	8.884	4.867	6.598	.763	2.494	-1.726	.005
6.50	7.866	9.586	5.599	7.319	1.254	2.974	-1.214	.506

Table 10. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Ylg. clean fleece weight (lbs.)								
				a(r) = (.1, 0, 0)				
4.70	4.825	6.601	2.463	4.239	-.841	.933	-3.413	-1.638
5.15	5.571	7.347	3.209	4.984	-.332	1.433	-2.904	-1.128
5.60	6.319	8.095	3.957	5.733	.179	1.955	-2.392	-.616
6.05	7.071	8.847	4.709	6.484	.693	2.469	-1.878	-.102
6.50	7.825	9.601	5.463	7.239	1.209	2.985	-1.362	.413
				a(r) = (.1, 0, .3)				
4.70	4.825	6.601	2.463	4.239	-.841	.933	-3.413	-1.638
5.15	5.862	7.638	3.500	5.276	-.132	1.642	-2.704	-.929
5.60	6.633	8.408	4.270	6.046	.394	2.169	-2.177	-.402
6.05	7.406	9.182	5.044	6.819	.923	2.698	-1.648	.126
6.50	8.182	9.958	5.820	7.596	1.453	3.229	-1.118	.657
				a(r) = (.1, .25, 0)				
4.70	4.889	6.676	2.508	4.294	-.801	.984	-3.394	-1.607
5.15	5.698	7.496	3.297	5.095	-.251	1.546	-2.865	-1.067
5.60	6.510	8.319	4.091	5.900	.300	2.109	-2.333	-.524
6.05	7.325	9.146	4.887	6.707	.854	2.674	-1.799	.020
6.50	8.143	9.975	5.685	7.517	1.410	3.242	-1.264	.566

Table 10. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Ylg. clean fleece weight (lbs.)								
				a(r) = (.1, .25, .3)				
4.70	4.889	6.676	2.508	4.294	-.801	.984	-3.394	-1.607
5.15	5.989	7.787	3.589	5.387	-.052	1.745	-2.666	-.868
5.60	6.823	8.632	4.404	6.213	.514	2.323	-2.119	-.310
6.05	7.660	9.480	5.222	7.042	1.083	2.903	-1.570	.249
6.50	8.500	10.331	6.042	7.873	1.654	3.486	-1.020	.810

Table 11. Influence of yearling clean fleece weight on profit potential (π_{21}) for different combinations of relationships in a range sheep enterprise producing feeder lambs

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Ylg. clean fleece weight (lbs.)								
3.75	4.209	5.028	2.718	3.537	.045	.864	-1.473	-.654
	$a(r_{5:8}, r_{81:41}, r_{141:41}) = a(r)$							
	$a(r) = (0, -.25, 0)$							
4.20	4.914	5.727	3.436	4.250	.522	1.336	-.981	-.167
4.65	5.623	6.431	4.159	4.967	1.003	1.811	-.486	.321
5.10	6.336	7.138	4.886	5.689	1.487	2.289	.010	.813
5.55	7.052	7.850	5.616	6.414	1.973	2.770	.510	1.308
6.00	7.772	8.564	6.350	7.142	2.461	3.253	1.013	1.805
	$a(r) = (0, -.25, .3)$							
4.20	4.914	5.727	3.436	4.250	.522	1.336	-.981	-.167
4.65	5.623	6.431	4.159	4.967	1.003	1.811	-.486	.321
5.10	6.336	7.138	4.886	5.689	1.487	2.289	.010	.813
5.55	7.052	7.850	5.616	6.414	1.973	2.770	.510	1.308
6.00	8.546	9.338	7.124	7.915	2.990	3.782	1.542	2.334

Table 11. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Ylg. clean fleece weight (lbs.)								
				a(r) = (0, 0, 0) a(r) = (.1, 0, 0)				
4.20	4.980	5.799	3.489	4.308	.572	1.391	-.946	-.126
4.65	5.755	6.575	4.264	5.083	1.102	1.921	-.415	.403
5.10	6.535	7.354	5.044	5.863	1.635	2.454	.117	.936
5.55	7.318	8.137	5.827	6.646	2.171	2.990	.652	1.471
6.00	8.104	8.923	6.613	7.432	2.708	3.528	1.190	2.009
				a(r) = (0, 0, .3) a(r) = (.1, 0, .3)				
4.20	4.980	5.799	3.489	4.308	.572	1.391	-.946	-.126
4.65	5.755	6.575	4.264	5.083	1.102	1.921	-.415	.403
5.10	6.535	7.354	5.044	5.863	1.635	2.454	.117	.936
5.55	7.318	8.137	5.827	6.646	2.171	2.990	.652	1.471
6.00	8.877	9.697	7.386	8.205	3.237	4.057	1.719	2.538

Table 11. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Ylg. clean fleece weight (lbs.)								
	a(r) = (0, .25, 0)							
4.20	5.047	5.871	3.542	4.366	.621	1.446	-.910	-.086
4.65	5.888	6.718	4.369	5.199	1.201	2.031	-.344	.485
5.10	6.734	7.569	5.201	6.037	1.784	2.619	.223	1.059
5.55	7.583	8.424	6.037	6.878	2.369	3.210	.795	1.635
6.00	8.436	9.282	6.876	7.722	2.956	3.803	1.368	2.214
	a(r) = (0, .25, .3)							
4.20	5.047	5.871	3.542	4.366	.621	1.446	-.910	-.086
4.65	5.888	6.718	4.369	5.199	1.201	2.031	-.344	.485
5.10	6.734	7.569	5.201	6.037	1.784	2.619	.223	1.059
5.55	7.583	8.424	6.037	6.878	2.369	3.210	795	1.635
6.00	9.210	10.056	7.649	8.496	3.485	4.332	1.897	2.743
	a(r) = (.1, -.25, 0)							
4.20	4.875	5.689	3.403	4.217	.490	1.304	-1.007	-.194
4.65	5.546	6.354	4.093	4.901	.940	1.748	-.538	.269
5.10	6.222	7.024	4.788	5.591	1.393	2.195	-.066	.735
5.55	6.902	7.699	5.487	6.284	1.849	2.645	.408	1.205
6.00	7.586	8.378	6.191	6.982	2.308	3.099	.886	1.677

Table 11. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Ylg. clean fleece weight (lbs.)								
				a(r) = (.1, -.25, .3)				
4.20	4.875	5.689	3.403	4.217	.490	1.304	-1.007	-.194
4.65	5.546	6.354	4.093	4.901	.940	1.748	-.538	.269
5.10	6.222	7.024	4.788	5.591	1.393	2.195	-.066	.735
5.55	6.902	7.699	5.487	6.284	1.849	2.645	.408	1.205
6.00	8.360	9.151	6.964	7.755	2.837	3.628	1.415	2.206
				a(r) = (.1, .25, 0)				
4.20	5.086	5.911	3.575	4.400	.654	1.478	-.883	-.059
4.65	5.968	6.798	4.438	5.268	1.267	2.097	-.290	.539
5.10	6.854	7.690	5.305	6.140	1.883	2.719	.305	1.141
5.55	7.745	8.586	6.176	7.017	2.502	3.344	.905	1.746
6.00	8.640	9.487	7.051	7.898	3.125	3.972	1.507	2.354

Table 11. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Ylg. clean fleece weight (lbs.)								
	a(r) = (.1, .25, .3)							
4.20	5.086	5.911	3.575	4.400	.654	1.478	-.883	-.059
4.65	5.968	6.798	4.438	5.268	1.267	2.097	-.290	.539
5.10	6.854	7.690	5.305	6.140	1.883	2.719	.305	1.141
5.55	7.745	8.586	6.176	7.017	2.502	3.344	.905	1.746
6.00	9.413	10.260	7.824	8.671	3.654	4.501	2.036	2.883

(0, 0, .3) were compared, a sharp increase in the rate of change of profit potential was noted for the range flock producing feeder lambs. This abrupt increase is due to the higher price received per pound of clean wool. The correlated response in staple length was enough to raise the classification of the wool from fine French combing to fine staple. In actual practice one would expect a more gradual change over the range of fleece weights used in this study. When the average staple is increased only a little, some of the fleeces will fall in a higher price range. When the average staple length is increased sufficiently to be in the higher price range, some fleeces will be shorter than average, and others longer, so the change in actual profit potential will be more regular than shown here.

Very little inter-relationship between combinations of price and the assumed genetic relationships was observed except to note that at the high level of wool and lamb prices, positive genetic relationships produced a greater rate of change in profit than they did at the low level of lamb and wool prices. The two levels of feed prices used had little influence on the rate of change of profit potential for range enterprises.

Importance of Weaning Weight in Range Sheep Enterprises

Wool income, salvage ewe and lamb income and ewe and replacement feed cost for the various combinations of prices, genetic correlations and levels of weaning weight for range sheep enterprises have been presented in Appendix Tables 28 through 33.

Profit potentials per breeding ewe in range enterprises for different levels of weaning weight have been presented in Tables 12 and 13.

In evaluating the changes in profit potentials from the changes in weaning weight several considerations have to be kept in mind, particularly if one wants to compare changes in profit potentials due to different selection goals. Values examined for weaning weight ranged over approximately 3 genic standard deviations while those for yearling clean fleece weight ranged over some 4.5 genic standard deviations. In range enterprises producing both milk-fat and feeder lambs, a constant weight limitation was imposed on the market weight for milk-fat lambs. This limitation was not unreasonable because of the commonly accepted practice of "topping-off" groups of lambs as they reach acceptable market weights. In the case of both types of range enterprises weaning weight per breeding ewe was essentially adjusted downward for ewe lambs that need be kept for replacement purposes. Still another consideration was an underlying assumption that no increase in feed consumption or expense was necessary for higher levels of wool production. This assumption was questionable, but here actual data to support or refute the assumption were not available in the literature.

Table 12. Influence of weaning weight on profit potential (π_{12}) for different combinations of relationships in a range sheep enterprise producing milk-fat and feeder lambs.

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Weaning weight (lbs.)								
74.00	4.084	5.859	1.721	3.497	-1.349	.426	-3.921	-2.145
$a(r_{5:8}, r_{81:41}, r_{141:10}) = a(r)$								
$a(r) = (0, -.25, 0)$								
76.75	4.321	6.109	1.908	3.697	-1.159	.629	-3.785	-1.997
79.50	4.550	6.351	2.088	3.889	-.975	.825	-3.655	-1.854
82.25	4.771	6.584	2.261	4.075	-.798	1.014	-3.531	-1.717
85.00	4.984	6.809	2.428	4.253	-.628	1.197	-3.411	-1.586
87.75	5.188	7.026	2.587	4.425	-.464	1.373	-3.297	-1.459
$a(r) = (0, -.25, .20)$								
76.75	4.321	6.109	1.908	3.697	-1.159	.629	-3.785	-1.997
79.50	4.550	6.351	2.088	3.889	-.975	.825	-3.655	-1.854
82.25	4.771	6.584	2.261	4.075	-.798	1.014	-3.531	-1.717
85.00	5.225	7.051	2.669	4.495	-.462	1.363	-3.246	-1.420
87.75	5.429	7.267	2.827	4.665	-.299	1.538	-3.133	-1.295

Table 12. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Weaning weight (lbs.)								
				a(r) = (0, 0, 0)				
76.75	4.369	6.157	1.956	3.745	-1.126	.662	-3.753	-1.964
79.50	4.646	6.447	2.184	3.985	-.909	.891	-3.590	-1.789
82.25	4.915	6.729	2.406	4.219	-.699	1.113	-3.432	-1.619
85.00	5.176	7.002	2.620	4.446	-.496	1.329	-3.280	-1.454
87.75	5.429	7.267	2.827	4.665	-.299	1.538	-3.133	-1.295
				a(r) = (0, 0, .20)				
76.75	4.369	6.157	1.956	3.745	-1.126	.662	-3.753	-1.964
79.50	4.646	6.447	2.184	3.985	-.909	.891	-3.590	-1.789
82.25	4.915	6.729	2.406	4.219	-.699	1.113	-3.432	-1.619
85.00	5.423	7.249	2.867	4.693	-.327	1.498	-3.110	-1.285
87.75	5.676	7.514	3.075	4.913	-.130	1.707	-2.964	-1.126
				a(r) = (0, .25, 0)				
76.75	4.417	6.205	2.004	3.793	-1.093	.695	-3.720	-1.931
79.50	4.742	6.543	2.281	4.082	-.843	.957	-3.524	-1.723
82.25	5.060	6.873	2.550	4.363	-.601	1.212	-3.333	-1.520
85.00	5.369	7.194	2.813	4.638	-.364	1.460	-3.148	-1.322
87.75	5.669	7.507	3.068	4.906	-.135	1.702	-2.968	-1.130

Table 12. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Weaning weight (lbs.)								
	a(r) = (0, .25, .20)							
76.75	4.417	6.205	2.004	3.793	-1.093	.695	-3.720	-1.931
79.50	4.742	6.543	2.281	4.082	-.843	.957	-3.524	-1.723
82.25	5.060	6.873	2.550	4.363	-.601	1.212	-3.333	-1.520
85.00	5.622	7.447	3.066	4.891	-.191	1.633	-2.975	-1.149
87.75	5.924	7.762	3.323	5.160	.038	1.876	-2.794	-.956
	a(r) = (.1, -.25, 0)							
76.75	4.372	6.161	1.952	3.741	-1.116	.671	-3.751	-1.962
79.50	4.654	6.456	2.178	3.980	-.889	.912	-3.585	-1.783
82.25	4.931	6.745	2.399	4.214	-.666	1.148	-3.423	-1.608
85.00	5.201	7.028	2.615	4.442	-.447	1.378	-3.264	-1.438
87.75	5.466	7.305	2.826	4.665	-.234	1.604	-3.110	-1.271
	a(r) = (.1, -.25, .20)							
76.75	4.372	6.161	1.952	3.741	-1.116	.671	-3.751	-1.962
79.50	4.654	6.456	2.178	3.980	-.889	.912	-3.585	-1.783
82.25	4.931	6.745	2.399	4.214	-.666	1.148	-3.423	-1.608
85.00	5.443	7.270	2.857	4.684	-.282	1.544	-3.099	-1.272
87.75	5.706	7.545	3.066	4.905	-.070	1.768	-2.946	-1.106

Table 12. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Weaning weight (lbs.)								
				a(r) = (.1, 0, 0)				
76.75	4.420	6.209	2.000	3.789	-1.083	.704	-3.718	-1.929
79.50	4.751	6.552	2.274	4.076	-.823	.978	-3.519	-1.718
82.25	5.075	6.890	2.544	4.358	-.567	1.246	-3.324	-1.510
85.00	5.394	7.221	2.807	4.634	-.316	1.510	-3.133	-1.306
87.75	5.706	7.545	3.066	4.905	-.070	1.768	-2.946	-1.106
				a(r) = (.1, 0, .20)				
76.75	4.420	6.209	2.000	3.789	-1.083	.704	-3.718	-1.929
79.50	4.751	6.552	2.274	4.076	-.823	.978	-3.519	-1.718
82.25	5.075	6.890	2.544	4.358	-.567	1.246	-3.324	-1.510
85.00	5.641	7.468	3.055	4.882	-.147	1.679	-2.964	-1.137
87.75	5.953	7.793	3.313	5.153	.098	1.938	-2.777	-.939
				a(r) = (.1, .25, 0)				
76.75	4.468	6.257	2.048	3.837	-1.051	.737	-3.685	-1.896
79.50	4.847	6.648	2.371	4.172	-.757	1.044	-3.453	-1.652
82.25	5.220	7.034	2.688	4.502	-.468	1.345	-3.225	-1.411
85.00	5.586	7.413	3.000	4.827	-.184	1.642	-3.001	-1.174
87.75	5.947	7.786	3.307	5.146	.094	1.933	-2.781	-.942

Table 12. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Weaning weight (lbs.)								
	a(r) = (.1, .25, .20)							
76.75	4.468	6.257	2.048	3.837	-1.051	.737	-3.685	-1.896
79.50	4.847	6.648	2.371	4.172	-.757	1.044	-3.453	-1.652
82.25	5.220	7.034	2.688	4.502	-.468	1.345	-3.225	-1.411
85.00	5.839	7.666	3.253	5.080	-.011	1.815	-2.828	-1.011
87.75	6.201	8.040	3.561	5.401	.268	2.107	-2.607	-.768

Table 13. Influence of weaning weight on profit potential (π_{22}) for different combinations of relationships in a range sheep enterprise producing feeder lambs

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Weaning weight (lbs.)								
70.00	4.209	5.208	2.718	3.537	.045	.864	-1.473	-.654
$a(r_{5:8}, r_{81:41}, r_{141:10}) = a(r)$								
$a(r) = (0, -.25, 0)$ $a(r) = (0, -.25, .20)$								
72.75	4.522	5.347	2.975	3.801	.304	1.130	-1.270	-.445
75.50	4.834	5.666	3.232	4.064	.564	1.396	-1.067	-.235
78.25	5.147	5.985	3.490	4.328	.824	1.662	-.864	-.025
81.00	5.460	6.305	3.748	4.592	1.084	1.929	-.660	.184
83.75	5.774	6.625	4.006	4.857	1.345	2.196	-.456	.394
$a(r) = (0, 0, 0)$ $a(r) = (0, 0, .20)$								
72.75	4.572	5.397	3.025	3.850	.338	1.164	-1.236	-.410
75.50	4.934	5.766	3.332	4.164	.632	1.464	-.999	-.167
78.25	5.297	6.135	3.639	4.478	.926	1.765	-.761	.076
81.00	5.660	6.505	3.947	4.792	1.221	2.066	-.524	.320
83.75	6.024	6.875	4.255	5.107	1.516	2.367	-.285	.565

Table 13. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Weaning weight (lbs.)								
	a(r) = (0, .25, 0) a(r) = (0, .25, .20)							
72.75	4.621	5.447	3.075	3.900	.372	1.198	-1.202	-.376
75.50	5.034	5.866	3.432	4.264	.700	1.532	-.931	-.099
78.25	5.447	6.285	3.789	4.628	1.029	1.867	-.659	.179
81.00	5.860	6.705	4.147	4.992	1.358	2.203	-.387	.457
83.75	6.274	7.125	4.506	5.357	1.687	2.538	-.114	.736
	a(r) = (.1, -.25, 0) a(r) = (.1, -.25, .20)							
72.75	4.566	5.392	3.013	3.839	.341	1.166	-1.240	-.414
75.50	4.926	5.759	3.311	4.144	.640	1.412	-1.004	-.172
78.25	5.290	6.129	3.613	4.452	.942	1.781	-.766	.072
81.00	5.658	6.504	3.918	4.763	1.248	2.093	-.525	.319
83.75	6.030	6.882	4.226	5.078	1.557	2.409	-.282	.569

Table 13. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Weaning weight (lbs.)								
	a(r) = (.1, 0, 0) a(r) = (.1, 0, .20)							
72.75	4.616	5.442	3.063	3.889	.375	1.200	-1.206	-.380
75.50	5.026	5.858	3.411	4.244	.708	1.540	-.936	-.104
78.25	5.440	6.279	3.763	4.602	1.045	1.884	-.664	.174
81.00	5.858	6.703	4.118	4.963	1.385	2.230	-.389	.456
83.75	6.280	7.131	4.476	5.328	1.728	2.579	-.111	.740
	a(r) = (.1, .25, 0) a(r) = (.1, .25, .20)							
72.75	4.666	5.492	3.113	3.939	.409	1.235	-1.172	-.346
75.50	5.126	5.958	3.511	4.344	.777	1.609	-.868	-.035
78.25	5.590	6.429	3.913	4.752	1.147	1.986	-.561	.277
81.00	6.058	6.903	4.318	5.163	1.521	2.367	-.252	.592
83.75	6.530	7.382	4.726	5.578	1.899	2.750	-.059	.911

Highest profit potentials were attained for the combination of a high wool price, high salvage ewe and medium feed prices for both types of range enterprises. The level of feed price used affected the level of profit potentials more than it affected the rate of change of profit potential. When profit potentials from $a(r) = (r_{5:8}, r_{141:81}, r_{141:10}) = (.1, .25, 0)$ were compared with those from $a(r) = (0, .25, 0)$, a greater rate of increase was noted for the former together with a higher level of profit potential. Not only were the weaning weights predicted to be heavier but there were more lambs available for market. Slightly higher profit potentials were attained for $a(r) = (0, .25, 0)$ than for $(0, 0, 0)$ because of the positive genetic relationship assumed between heavier body weights and fleece production. Also $a(r) = (0, 0, 0)$ resulted in a higher profit potential than $a(r) = (0, -.25, 0)$ because of the negative genetic relationship assumed in the latter case.

Negative profit potentials were found when $a(P) = (M, L, H)$, when $a(P) = (L, L, H)$ and when $a(P) = (L, L, M)$. A range sheep enterprise would be untenable if those price combinations persisted for an appreciable period. Even at those price combinations which gave negative profit situations the relative rank of profit potentials for the various correlation vectors remained the same, *e.g.* the profit potentials from $a(r) = (.1, .25, 0)$ were greater than for $a(r) = (0, 0, 0)$ which in turn was greater than $a(r) = (0, -.25, 0)$.

When profit potentials from a(r) = (-, -, 0) were compared with profit potentials from a(r) = (-, -, .20) for a range enterprise producing both fat and feeder lambs, the rate of increase was not constant for a(r) = (-, -, .20). While this rate of increase was not of the magnitude described for the profit potentials for yearling clean fleece weight the pattern was similar. Possible reasons for this lack of consistency have already been advanced.

Influence of Yearling Grease Fleece Weight in a Farm Flock Sheep Enterprise

Salvage ewe and lamb income, wool income, ewe and replacement ewe feed cost and lamb supplemental feed cost for the various combinations of prices, genetic relationships and levels of yearling grease fleece weight production have been presented in Appendix Tables 34 through 37.

Profit potentials per breeding ewe in a farm flock enterprise for different levels of yearling grease fleece weight within the various combinations of prices and genetic relationships have been presented in Table 14.

The fixed cost used for farm flock enterprises was $5.00 less per breeding ewe than the fixed cost used for range enterprises. In spite of this, farm flock profit potentials were not as high as those for range enterprises at comparable price vectors. The main reason for the difference in profit potentials between the two types of enterprises was that supplemental feeding of lambs was assumed necessary and the

Table 14. Influence of yearling grease fleece weight on profit potential (π_{31}) for different combinations of relationships in a farm flock sheep enterprise

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Ylg. grease fleece weight (lbs.)								
9.0	2.565	5.997	-.128	3.303	-2.960	.470	-6.123	-2.692
	$a(r_{81:181}, r_{18:5}) = a(r)$							
				$a(r) = (0, 0)$				
9.5	2.908	6.339	.213	3.645	-2.726	.704	-5.889	-2.458
10.0	3.250	6.681	.556	3.987	-2.492	.938	-5.655	-2.224
10.5	3.592	7.024	.898	4.329	-2.258	1.173	-5.421	-1.990
11.0	3.934	7.366	1.240	4.672	-2.024	1.407	-5.187	-1.755
11.5	4.276	7.708	1.582	5.014	-1.790	1.641	-4.953	-1.521
				$a(r) = (0, .25)$				
9.5	3.367	6.806	.609	4.048	-2.346	1.092	-5.584	-2.145
10.0	4.170	7.616	1.349	4.795	-1.730	1.715	-5.044	-1.597
10.5	4.974	8.427	2.089	5.543	-1.113	2.339	-4.502	-1.049
11.0	5.778	9.239	2.831	6.291	-.496	2.964	-3.960	-.500
11.5	6.584	10.051	3.573	7.040	.122	3.589	-3.417	.050

Table 14. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Ylg. grease fleece weight (lbs.)								
	a(r) = (.5, 0)							
9.5	2.750	6.211	.053	3.514	-2.886	.574	-6.051	-2.590
10.0	2.934	6.424	.236	3.726	-2.812	.677	-5.979	-2.489
10.5	3.119	6.638	.418	3.937	-2.738	.780	-5.907	-2.388
11.0	3.303	6.851	.600	4.148	-2.664	.883	-5.835	-2.287
11.5	3.488	7.065	.783	4.360	-2.590	.986	-5.762	-2.185
	a(r) = (.5, .25)							
9.5	3.209	6.677	.449	3.918	-2.506	.961	-5.746	-2.278
10.0	3.854	7.359	1.029	4.533	-2.050	1.454	-5.367	-1.863
10.5	4.500	8.041	1.609	5.150	-1.593	1.946	-4.988	-1.447
11.0	5.148	8.724	2.191	5.768	-1.135	2.440	-4.607	-1.031
11.5	5.796	9.408	2.773	6.386	-.677	2.935	-4.226	-.613

appropriate cost assessed accordingly. The minimum charge made against a farm flock sheep enterprise for lamb supplemental feed in any price combination was $5.08 per breeder ewe.

Substantial differences in rate of change of profit potentials in favor of a positive correlation of yearling grease fleece weight and lambing rate were found when profit potentials from $a(r) = (r_{81:181}, r_{18:5}) = (-, .25)$ and $a(r) = (-, 0)$ were compared. It is difficult to visualize that lambing rate and yearling grease fleece weight might be correlated that high genetically, but if .25 were the parameter, profits from farm flock ewes could be increased by the inclusion of lambing rate as a selection criteria.

When profit potentials $a(r) = (0, -)$ were compared with profit potentials from $a(r) = (.5, 0)$, the profit potentials of the latter were lower. Body weight itself added to higher feed costs of the breeding ewes without any additional benefit. It is difficult to visualize high levels of fleece weight production in farm flock ewes without increased body weights. The most favorable combination for the greatest rate of change in profit potential in a farm flock sheep enterprise would be at the highest level of wool, salvage ewe and lamb prices with the medium feed price level and a positive genetic correlation between fleece weight and lambing rate and a zero correlation between fleece weight and body size.

Importance of Lambing Rate in a Farm Flock Sheep Enterprise

Salvage ewe and lamb income, wool income, ewe and replacement feed cost and lamb supplemental feed cost for the various combinations of prices and genetic relationships and lambing rates have been presented in Appendix Tables 38 through 41.

Profit potentials per breeding ewe in a farm flock enterprise for different lambing rates within the various combinations of prices and genetic relationships have been presented in Table 15.

Profit potentials obtained when lambing rates were increased differed in level of profit over the different price combinations but the rates of change of profit potentials within given combinations of prices were not as marked for the different correlations as were the rates of change of profit potentials when yearling grease fleece weights were increased.

The relative rank of the correlation vectors did not change over all combinations of prices used for the farm flock enterprises. The rate of change of profit was the highest when $a(r) = (r_{5:8}, r_{5:18}) = (0, .25)$ followed in succeeding order by $a(r) = (.1, .25)$, $a(r) = (0, 0)$ and $a(r) = (.1, 0)$.

When the correlation of body weight and lambing rate was changed from 0 to .1 the rate of change of profit potential decreased. The added income from salvage or aged ewes

Table 15. Influence of lambing rate on profit potential (π_{32}) for different combinations of relationships in a farm flock sheep enterprise

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Lambing rate (%)								
140	2.565	5.997	-.128	3.303	-2.960	.470	-6.123	-2.692
	$a(r_{5:8}, r_{18:5}) = a(r)$							
				$a(r) = (0, 0)$				
145	3.386	6.831	.579	4.024	-2.280	1.164	-5.577	-2.133
150	4.211	7.668	1.290	4.748	-1.596	1.860	-5.028	-1.571
155	5.039	8.508	2.005	5.474	-.910	2.559	-4.476	-1.007
160	5.869	9.350	2.722	6.203	-.221	3.260	-3.921	-.440
165	6.701	10.195	3.441	6.935	.470	3.964	-3.364	.128
				$a(r) = (0, .25)$				
145	3.422	6.867	.615	4.060	-2.255	1.188	-5.553	-2.108
150	4.283	7.740	1.362	4.819	-1.547	1.909	-4.979	-1.522
155	5.146	8.616	2.112	5.582	-.836	2.632	-4.403	-.933
160	6.012	9.494	2.865	6.347	-.123	3.358	-3.824	-.342
165	6.880	10.374	3.620	7.113	.593	4.086	-3.242	.251

Table 15. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H	M	H	M	H	M	H	M
Lambing rate (%)								
				a(r) = (.1, 0)				
145	3.372	6.820	.565	4.012	-2.294	1.152	-5.592	-2.145
150	4.183	7.645	1.262	4.724	-1.625	1.837	-5.057	-1.595
155	4.996	8.474	1.962	5.439	-.953	2.524	-4.520	-1.042
160	5.812	9.304	2.664	6.157	-.278	3.213	-3.979	-.487
165	6.631	10.137	3.370	6.876	.399	3.905	-3.437	.069
				a(r) = (.1, .25)				
145	3.408	6.855	.601	4.048	-2.270	1.177	-5.567	-2.120
150	4.254	7.717	1.333	4.796	-1.576	1.886	-5.008	-1.546
155	5.104	8.581	2.069	5.547	-.879	2.597	-4.446	-.969
160	5.955	9.448	2.808	6.300	-.180	3.311	-3.882	-.389
165	6.810	10.316	3.549	7.055	.521	4.027	-3.314	.191

was not enough to compensate for the added expense due to increased body weight and lamb production.

The effect on rate of change of profit potential of a positive correlation between lambing rate and fleece weight as measured by the difference between a(r) = (-, 0) and a(r) = (-, .25) was slight but favorable, but the differences were of small magnitude as compared with the differences in profit potential when yearling grease fleece weight was increased. Slightly higher rates of change of profit potential were found for the medium level of feed prices than for the high level of feed prices.

CONCLUSIONS

In order to compare the changes in profit potentials and have some measure of the rates of change of profit potentials Tables 16 through 21 were prepared. Differences between the profit potentials for the various levels of production under consideration within price and genetic relationships were about the same. As a consequence the differences in profit potentials between levels were averaged to have a basis for comparing rates of change for the various combinations of price and genetic relationships.

The near linear response of changes in profit potentials to changes in production levels of traits considered was probably due in part to the assumptions that the regression of feed consumption on adult body weight was linear and that changes in wool production could come about without affecting feed consumption. Further data are needed to examine the validity of these assumptions. Furthermore, the assumption that genetic correlations would remain constant over the levels of performance studied is open to question. Some of the genetic correlations could change rather drastically as gene frequencies changed in response to selection for higher levels of production.

Tables 16 through 19 show the average rates of change of profit potentials for yearling clean fleece weight and weaning weight, respectively, for the different combinations

Table 16. Average rates of change of profit potentials per pound increase in yearling clean fleece weight for different combinations and genetic relationships for milk-fat and feeder lamb range enterprise

Genetic correlations between			Price vector								
Lambing rate & body weight	Ylg. body weight & ylg. clean fleece weight	Ylg. staple length & ylg. clean fleece weight	Mutton Wool Feed	H H H	H H M	M H H	M H M	M L H	M L M	L L H	L L M
0	-.25	0		$1.620	1.598	1.649	1.627	1.131	1.107	1.162	1.135
0	-.25	.30		1.784	1.755	1.809	1.784	1.282	1.215	1.269	1.302
0	0	0		1.662	1.662	1.662	1.662	1.138	1.138	1.138	1.138
0	0	.30		1.822	1.822	1.822	1.822	1.244	1.244	1.244	1.244
0	.25	0		1.700	1.724	1.673	1.695	1.140	1.164	1.111	1.133
0	.25	.30		1.856	1.882	1.831	1.698	1.249	1.273	1.220	1.298
.10	-.25	0		1.522	1.498	1.564	1.540	1.049	1.024	1.093	1.069
.10	-.25	.30		1.680	1.655	1.724	1.700	1.158	1.184	1.202	1.178
.10	0	0		1.662	1.662	1.662	1.662	1.138	1.138	1.138	1.138
.10	0	.30		1.822	1.822	1.822	1.822	1.244	1.244	1.244	1.244
.10	.25	0		1.804	1.829	1.760	1.786	1.227	1.251	1.180	1.204
.10	.25	.30		1.962	1.986	1.920	1.944	1.335	1.360	1.289	1.313

Table 17. Average rates of change of profit potentials per pound increase in yearling clean fleece weight for different combinations of price and genetic relationships for feeder lamb range enterprises

Genetic correlations between: Lambing rate & body weight	Ylg. body weight & ylg. clean fleece weight	Ylg. staple length & ylg. clean fleece weight	Price vector: Mutton / Wool / Feed	H / H / H	H / H / M	M / H / H	M / H / M	M / L / H	M / L / M	L / L / H	L / L / M
0	-.25	0		$1.584	1.611	1.613	1.602	1.073	1.062	1.104	1.093
0	-.25	.30		1.926	1.915	1.958	1.946	1.309	1.298	1.340	1.329
0	0	0		1.731	1.731	1.731	1.731	1.184	1.184	1.184	1.184
0	0	.30		2.075	2.075	2.075	2.075	1.418	1.418	1.418	1.418
0	.25	0		1.878	1.891	1.849	1.859	1.293	1.307	1.262	1.275
0	.25	.30		2.000	2.235	2.191	2.204	1.529	1.542	1.498	1.509
.10	-.25	0		1.500	1.489	1.544	1.531	1.007	.993	1.049	1.035
.10	-.25	.30		1.844	1.538	1.886	1.875	1.240	1.229	1.284	1.271
.10	0	0		1.731	1.731	1.731	1.731	1.184	1.184	1.184	1.184
.10	0	.30		2.075	2.075	2.075	2.075	1.418	1.418	1.418	1.418
.10	.25	0		1.969	1.982	1.926	1.938	1.369	1.382	1.324	1.338
.10	.25	.30		2.313	2.324	2.269	2.282	1.604	1.615	1.560	1.571

Table 18. Average rates of change of profit potential per pound increase in weaning weight for different combinations of price and genetic relationships for milk-fat feeder lamb range enterprises

Genetic correlations between: Lambing rate & body weight	Ylg. body weight & ylg. clean fleece weight	Ylg. staple length & weaning weight	Price vector:								
			Mutton	H	H	M	M	M	M	L	L
			Wool	H	H	H	H	L	L	L	L
			Feed	H	M	H	M	H	M	H	M
0	-.25	0		$.080	.085	.063	.068	.064	.069	.045	.050
0	-.25	.20		.098	.103	.080	.085	.076	.081	.057	.062
0	0	0		.098	.103	.080	.085	.076	.081	.057	.062
0	0	.20		.116	.120	.099	.103	.089	.093	.069	.074
0	.25	0		.115	.120	.098	.103	.088	.093	.069	.074
0	.25	.20		.134	.139	.116	.121	.101	.105	.082	.087
.10	-.25	0		.100	.105	.080	.085	.081	.086	.059	.064
.10	-.25	.20		.118	.123	.098	.103	.093	.097	.071	.076
.10	0	0		.118	.123	.098	.103	.093	.097	.071	.076
.10	0	.20		.136	.141	.116	.120	.105	.110	.083	.088
.10	.25	0		.136	.140	.115	.120	.105	.109	.083	.088
.10	.25	.20		.154	.159	.134	.139	.117	.122	.096	.100

Table 19. Average rates of change of profit potential per pound increase in weaning weight for different combinations of price and genetic relationships for feeder lamb range enterprises

Genetic correlations between: Lambing rate & body weight	Ylg. body weight & ylg. clean fleece weight	Ylg. staple length & weaning weight	Price vector: Mutton H, Wool H, Feed H	Mutton H, Wool H, Feed M	Mutton M, Wool H, Feed H	Mutton M, Wool H, Feed M	Mutton M, Wool L, Feed H	Mutton M, Wool L, Feed M	Mutton L, Wool L, Feed H	Mutton L, Wool L, Feed M
0	-.25	0	$.114	.103	.094	.096	.096	.097	.074	.076
0	-.25	.20	.114	.103	.094	.096	.096	.097	.074	.076
0	0	0	.132	.121	.112	.114	.107	.109	.087	.089
0	0	.20	.132	.121	.112	.114	.107	.109	.087	.089
0	.25	0	.150	.139	.130	.132	.119	.122	.099	.101
0	.25	.20	.150	.139	.130	.132	.119	.122	.099	.101
.10	-.25	0	.132	.122	.110	.112	.110	.112	.087	.072
.10	-.25	.20	.132	.122	.110	.112	.110	.112	.087	.072
.10	0	0	.151	.140	.128	.130	.123	.125	.099	.101
.10	0	.20	.151	.140	.128	.130	.123	.125	.099	.101
.10	.25	0	.169	.158	.146	.148	.135	.137	.103	.114
.10	.25	.20	.169	.158	.146	.148	.135	.137	.103	.114

of price and genetic relationships in range enterprises. Highest rates of change of profit potentials in this study were associated with high prices for products, medium feed costs, and positive genetic relationships. Lowest rates of change were associated with low prices for products, high feed prices and zero or negative correlations.

Average rates of change of profit potentials in range enterprises were higher for the range enterprises producing feeder lambs and were partially due to different feed costs used. In range enterprises increasing clean fleece weight resulted in higher profit potentials and in higher rates of change of profit potential. Lower rates of change of profit potential were found with a negative relationship between body weight and clean fleece weight. A positive relationship between lambing rate and body weight did not materially affect the rate of change of profit potential, probably because the assumed correlation of .1 between the two traits was low. A positive correlation of clean fleece weight and staple length resulted in higher rates of change of profit potential than a correlation of zero between the two traits.

Average rates of change of profit potential for increased weaning weight were higher when the medium level of feed price was used than for the high level except for the combination of a high level of income and a high feed price in the range enterprise producing feeder lambs. A negative relationship between body weight and clean fleece production depressed rates of change of profit potential due to the resulting lowered wool production and slightly higher feed cost. Higher rates of change of profit potential were observed when the genetic correlation between lambing rate and body weight was positive as weaning weights increased. Rates of change of profit potentials were markedly in favor of high wool price.

Tables 20 and 21 show the average rates of change for yearling grease fleece weight and lambing rate respectively, for different combinations of price and genetic relationships for a farm flock enterprise. The rates of change of profit potentials that are presented in Table 21 have been projected to an additional lamb increase in order to present results on a whole unit basis. These rates of change of profit potentials for increasing lambing rate may not be realistic for levels of production outside the range (140--165%) of values considered in this study.

Rates of change of profit potentials for yearling grease fleece weight fluctuated in response to assumed genetic relationships. The inclusion of a genetic correlation between lambing rate and fleece weight of .25 resulted in the highest profit potentials attained for yearling grease fleece weight. The inclusion of a genetic correlation of fleece weight and body weight of .5 markedly depressed rates of change of profit

Table 20. Average rates of change of profit potentials per pound of increase in yearling grease fleece weight for different combinations of price and genetic relationships for a farm flock enterprise

Genetic correlations between: Ylg. body weight & grease fleece weight	Genetic correlations between: Lambing rate & ylg. grease fleece weight	Price vector								
		Mutton	H	H	M	M	M	M	L	L
		Wool	H	H	H	H	L	L	L	L
		Feed	H	M	H	M	H	M	H	M
0	0		$ .684	.684	.684	.684	.468	.468	.468	.468
0	.25		1.608	1.842	1.480	1.496	1.232	1.248	1.082	1.096
.5	0		.370	.428	.364	.422	.148	.206	.144	.202
.5	.25		1.292	1.364	1.160	1.234	.914	.986	.758	.832

Table 21. Average rates of change of profit potentials per additional lamb increase for different combinations of price and genetic relationships for a farm flock enterprise

Genetic correlations between: Body weight & lambing rate	Grease fleece weight & lambing rate		Price vector							
		Mutton	H	H	M	M	M	M	L	L
		Wool	H	H	H	H	L	L	L	L
		Feed	H	M	H	M	H	M	H	M
0	0		$16.54	16.78	14.28	14.52	13.72	13.98	11.04	11.32
0	.25		17.26	17.50	15.00	15.26	14.22	14.46	11.52	11.78
.1	0		16.28	16.56	14.80	14.30	13.44	13.74	10.74	11.04
.1	.25		16.98	17.32	14.70	15.00	13.92	14.22	11.24	11.54

potential because of the increase in total feed expense. When both genetic correlations were included the resultant rates of change of profit potentials was intermediate between the two extremes. Levels of feed costs for ewes, lambs and replacements were an influencing factor on differences in rates of change of profit potentials.

While the addition of a positive genetic relationship of grease fleece weight and lambing rate increased the rates of change of profit potentials when lambing rates were increased, the increase was not as large as those observed when yearling grease fleece weight was changed. The slight but positive genetic correlation of .1 between lambing rate and body weight reduced the rates of change of profit potentials.

The average rates of change of profit potentials that have been presented in Tables 16 through 21 possibly have several uses. They could be used as a basis for estimating the relative merit of proposed selection programs for yearling clean fleece weight or for weaning weight in a range sheep enterprise, or in a farm flock the relative merit of selection for yearling grease fleece weight or lambing rate.

A knowledge of the average rates of change of profit potentials are useful in selection programs because they reflect the change in net income from overall performance expected to accrue from direct selection for a single trait. Because many traits are measured at different stages in life, selection is practiced at different ages, and aspects of the genotype other than for the particular trait or traits recently measured tend to be ignored. It is more correct to consider an aggregate genotype as consisting of the genotypes for individual traits as

$$H = a_1G_1 + a_2G_2 + \ldots.a_nG_n,$$

and the derived selection index, I, as

$$I = b_1P_1 + b_2P_2 + \ldots.b_nP_n.$$

Here the a's represent economic values for an individual trait, the G's represent the genotypes for the traits, the b's the partial regressions of the aggregate genotype on a particular trait and the P's the phenotypic values of the particular trait being measured.

Selection indexes usually have been developed independently for each age at which selection may be practiced and, aside from phenotypic and genetic variances and covariances, dependent upon different aggregate genotypes. The chief criticism of this practice is that of specifying different aggregate genotypes as an animal grows older. The genotype is determined at conception and as the mechanics of inheritance are now understood this genotype does not change. Why then should one attempt to describe different genotypes of the same individual for specific ages? There should be one aggregate genotype which includes all traits that contribute to the profit of the enterprise. Economic values obtained from average rates of change of profit potentials could then be assigned to traits that contribute directly to income which in the case of sheep would be wool production, weaning weight or pounds of lamb produced per breeder ewe. Other traits necessary to selection could be assigned economic values of zero in the aggregate genotype as follows:

$$H = a_1G_1 + a_2G_2 + 0G_3 + \ldots.0G_n,$$

in which G_1 could be clean fleece weight, G_2 weaning weight and G_3 lamb staple length, for example. Clean fleece weight and weaning weight contribute directly to income whereas lamb staple contributes only to subsequent income in the ewes because of its association with clean fleece weight and influence on the price of wool. A weaning index could be calculated using the overall genotype as a base but would incorporate traits ordinarily measured at weaning time, such as staple length, weaning weight and fleece grade, etc. A similar procedure could be followed for indexes at shearing or eighteen months.

SUMMARY

The principal objective of this study was to derive equations for and evaluate changes in profit potentials utilizing basic production traits for range and farm flock sheep enterprises.

Changes in profit potential in terms of dollars and cents per breeder ewe were used as the criteria of evaluation of an increase in the traits chosen for study.

Profit potential of a breeder ewe in a range sheep enterprise was thought of as a function not only of the price of aged ewes, wool, lamb and feed expense but also as a function of body weight, livability, pounds of clean wool production, lambing rate, feed consumption, rate of replacement of the breeding flock and fixed cost. Profit of a breeder ewe in a farm flock enterprise utilized the same levels of prices and the same production traits except that grease wool production was used instead of clean wool production and lamb feed consumption was included.

Profit potentials were computed for several price combinations and genetic relationships for changes in yearling clean fleece weight and weaning weight for range sheep enterprises producing milk-fat and feeder lambs and range sheep enterprises producing feeder lambs, and for changes in yearling grease fleece weight and lambing rate for farm flock sheep enterprises.

Eight combinations of different prices representing salvage ewe and lamb income, wool income and feed cost were used for the three types of enterprises. In range enterprises twelve combinations of genetic correlations between body weight and lambing rate, body weight and clean wool production, and staple length and clean wool production or staple length and weaning weight were examined. In farm flock enterprises four combinations of the genetic correlations between body weight and grease fleece weight, lambing rate and grease fleece weight were used for yearling grease fleece weight increases and the genetic correlations of lambing rate and body weight and lambing rate and grease fleece weight when lambing rate was increased. Rates of change of profit potentials due to changes in the traits studied were utilized to assess the influences of the various combinations of genetic correlations.

Highest rates of change of profit potential for range enterprises were associated with a high level of price for products, medium feed costs and positive genetic relationships. The lowest rates of change of profit potential for range enterprises were associated with low prices for products, high feed costs and negative genetic relationships. Rates of change of profit potentials for range enterprises producing feeder lambs were higher than rates of change of profit potentials for range enterprises producing milk-fat and feeder lambs and was due to the difference in feed cost used for the two types of enterprises. In range enterprises increasing clean fleece weight resulted in higher profit potentials and in higher rates of change of profit potential but on the questionable assumption that increased fleece weights could be attained with no increase in feed consumption or other expense.

Rates of change of profit potentials for increases in yearling grease fleece weight in a farm flock sheep enterprise fluctuated in response to assumed genetic relationships. The inclusion of a genetic correlation between fleece weight and body weight of .5 depressed rates of change of profit potential in a farm flock enterprise because of the increase in feed cost. The inclusion of a genetic correlation between fleece weight and lambing rate of .25 resulted in the highest profit potentials obtained in a farm flock enterprise when yearling grease fleece weights were increased. Levels of feed costs for ewes, lambs and replacements were an influencing factor on differences in rates of change of profit potentials in farm flock sheep enterprises.

The average rates of change of profit potentials for the traits under consideration in this study reflect the relative merits of the traits as selection criteria for flock improvement. Even when selection must be directed toward one or only a few of the traits which contribute to income, the changes expected to occur in the aggregate genotype are of primary importance from a genetic and economic standpoint.

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APPENDIX

Table 22. Influence of yearling clean fleece weight on salvage ewe and lamb income for different combinations of relationships in a range sheep enterprise producing milk-fat and feeder lambs

	Price vector			
Mutton Wool Feed	H H H H H , M	M M H H H , M	M M L L H , M	L L L L H , M
Ylg. clean fleece weight (lbs.)				
4.25	17.517	15.155	14.611	12.039
	$a(r_{5:8}, r_{81:41}, r_{141:41}) = a(r)$			
	a(r) = (0, -.25, 0) a(r) = (0, -.25, .3)			
4.70	17.424	15.074	14.533	11.974
5.15	17.330	14.993	14.454	11.910
5.60	17.235	14.911	14.375	11.845
6.05	17.140	14.829	14.296	11.779
6.50	17.045	14.747	14.217	11.714
	a(r) = (0, 0, 0) a(r) = (0, 0, .3)		a(r) = (.1, 0, 0) a(r) = (.1, 0, .3)	
4.70	17.517	15.155	14.611	12.039
5.15	17.517	15.155	14.611	12.039
5.60	17.517	15.155	14.611	12.039
6.05	17.517	15.155	14.611	12.039
6.50	17.517	15.155	14.611	12.039
	a(r) = (0, .25, 0) a(r) = (0, .25, .3)			
4.70	17.611	15.236	14.689	12.103
5.15	17.703	15.316	14.766	12.167
5.60	17.796	15.395	14.843	12.230
6.05	17.888	15.475	14.920	12.294
6.50	17.979	15.554	14.966	12.356

Table 22. (Continued)

	Price vector							
Mutton	H	H	M	M	M	M	L	L
Wool	H	H	H	H	L	L	L	L
Feed	H,	M	H,	M	H,	M	H,	M
Ylg. clean fleece weight (lbs.)								
			$a(r) = (.1, -.25, 0)$ $a(r) = (.1, -.25, .3)$					
4.70	17.376		15.033		14.493		11.942	
5.15	17.235		14.911		14.376		11.845	
5.60	17.094		14.789		14.258		11.748	
6.05	16.953		14.668		14.140		11.651	
6.50	16.813		14.546		14.023		11.554	
			$a(r) = (.1, .25, 0)$ $a(r) = (.1, .25, .3)$					
4.70	17.659		15.277		14.728		12.136	
5.15	17.800		15.399		14.846		12.233	
5.60	17.941		15.521		14.964		12.330	
6.05	18.082		15.643		15.082		12.427	
6.50	18.223		15.765		15.199		12.524	

Table 23. Influence of yearling clean fleece weight on wool income for different combinations of relationships in a range sheep enterprise producing milk-fat and feeder lambs

	Price vector	
Mutton	H H M M	M M L L
Wool	H H H H	L L L L
Feed	H , M H , M	H , M H , M
Ylg. clean fleece weight (lbs.)		
4.25	7.996	5.469
	$a(r_{5:8}, r_{81:41}, r_{141:41}) = a(r)$	
	a(r) = (0, -.25, 0) a(r) = (0, .25, 0) a(r) = (.1, 0, 0)	a(r) = (0, 0, 0) a(r) = (.1, -.25, 0) a(r) = (.1, .25, 0)
4.70	8.738	5.976
5.15	9.483	6.486
5.60	10.232	6.998
6.05	10.983	7.512
6.50	11.737	8.028
	a(r) = (0, -.25, .3) a(r) = (0, .25, .3) a(r) = (.1, 0, .3)	a(r) = (0, 0, .3) a(r) = (.1, -.25, .3) a(r) = (.1, .25, .3)
4.70	8.738	5.976
5.15	9.774	6.685
5.60	10.545	7.212
6.05	11.318	7.741
6.50	12.094	8.272

Table 24. Influence of yearling clean fleece weight on breeding ewe and replacement feed cost for different combinations of relationships in a sheep enterprise producing milk-fat and feeder lambs

	Price vector	
Mutton	H M M L	H M M L
Wool	H H L L	H H L L
Feed	H , H H , H	M , M M , M
Ylg. clean fleece weight (lbs.)		
4.25	12.430	10.564
	$a(r_{5:8}, r_{81:41}, r_{141:41}) = a(r)$	
	$a(r) = (0, -.25, 0)$ $a(r) = (0, -.25, .3)$	
4.70	12.354	10.589
5.15	12.279	10.525
5.60	12.203	10.460
6.05	12.127	10.395
6.50	12.051	10.330
	$a(r) = (0, 0, 0)$ $a(r) = (0, 0, .3)$	
4.70	12.430	10.654
5.15	12.430	10.654
5.60	12.430	10.654
6.05	12.430	10.654
6.50	12.430	10.654
	$a(r) = (0, .25, 0)$ $a(r) = (0, .25, .3)$	
4.70	12.506	10.719
5.15	12.581	10.784
5.60	12.657	10.849
6.05	12.732	10.913
6.50	12.808	10.978

Table 24. (Continued)

	Price vector	
Mutton Wool Feed	H M M L H H L L H , H H , H	H M M L H H L L M , M M , M
Ylg. clean fleece weight (lbs.)		
	a(r) = (.1, -.25, 0)	a(r) = (.1, -.25, .3)
4.70	12.352	10.588
5.15	12.275	10.521
5.60	12.197	10.455
6.05	12.119	10.388
6.50	12.042	10.321
	a(r) = (.1, 0, 0)	a(r) = (.1, 0, .3)
4.70	12.430	10.654
5.15	12.430	10.654
5.60	12.430	10.654
6.05	12.430	10.654
6.50	12.430	10.654
	a(r) = (.1, .25, 0)	a(r) = (.1, .25, .3)
4.70	12.508	10.721
5.15	12.585	10.787
5.60	12.663	10.854
6.05	12.740	10.920
6.50	12.818	10.986

Table 25. Influence of yearling clean fleece weight on salvage ewe and lamb income for different combinations of relationships in a range sheep enterprise producing feeder lambs .

	Price vector			
Mutton	H H	M M	M M	L L
Wool	H H	H H	L L	L L
Feed	H , M	H , M	H , M	H , M
Ylg. clean fleece weight (lbs.)				
3.75	10.722	9.231	8.896	7.378
	$a(r_{5:8}, r_{81:41}, r_{141:41}) = a(r)$			
	$a(r) = (0, .25, 0)$ $a(r) = (0, -.25, .3)$			
4.20	10.623	9.145	8.814	7.309
4.65	10.524	9.060	8.731	7.241
5.10	10.425	8.975	8.649	7.173
5.55	10.325	8.890	8.567	7.105
6.00	10.226	8.804	8.485	7.036
	$a(r) = (0, 0, 0)$ $a(r) = (0, 0, .3)$		$a(r) = (.1, 0, 0)$ $a(r) = (.1, 0, .3)$	
4.20	10.722	9.231	8.896	7.378
4.65	10.722	9.231	8.896	7.378
5.10	10.722	9.231	8.896	7.378
5.55	10.722	9.231	8.896	7.378
6.00	10.722	9.231	8.896	7.378
	$a(r) = (0, .25, 0)$ $a(r) = (0, .25, .3)$			
4.20	10.821	9.316	8.978	7.446
4.65	10.920	9.401	9.060	7.514
5.10	11.019	9.486	9.143	7.582
5.55	11.118	9.572	9.225	7.650
6.00	11.217	9.657	9.307	7.719

Table 25. (Continued)

	Price vector			
Mutton	H H	M M	M M	L L
Wool	H H	H H	L L	L L
Feed	H , M	H , M	H , M	H , M
Ylg. clean fleece weight (lbs.)				
		a(r) = (.1, -.25, 0) a(r) = (.1, -.25, .3)		
4.20	10.583	9.111	8.781	7.282
4.65	10.445	8.993	8.667	7.187
5.10	10.308	8.875	8.553	7.093
5.55	10.172	8.757	8.440	6.999
6.00	10.036	8.640	8.327	6.906
		a(r) = (.1, .25, 0) a(r) = (.1, .25, .3)		
4.20	10.861	9.350	9.011	7.473
4.65	11.001	9.471	9.127	7.570
5.10	11.142	9.592	9.244	7.666
5.55	11.283	9.714	9.361	7.764
6.00	11.425	9.836	9.479	7.861

Table 26. Influence of yearling clean fleece weight on wool income for different combinations of relationships in a range sheep enterprise producing feeder lambs

	Price vector	
Mutton	H H M M	M M L L
Wool	H H H H	L L L L
Feed	H , M H , M	H , M H , M
Ylg. clean fleece weight (lbs.)		
3.75	7.401	5.062
	$a(r_{5:8}, r_{81:41}, r_{141:41}) = a(r)$	
	$a(r) = (0, -.25, 0)$ $a(r) = (0, .25, 0)$ $a(r) = (.1, 0, 0)$	$a(r) = (0, 0, 0)$ $a(r) = (.1, -.25, 0)$ $a(r) = (.1, .25, 0)$
4.20	8.172	5.589
4.65	8.947	6.120
5.10	9.726	6.653
5.55	10.509	7.188
6.00	11.296	7.726
	$a(r) = (0, -.25, .3)$ $a(r) = (0, .25, .3)$ $a(r) = (.1, 0, .3)$	$a(r) = (0, 0, .3)$ $a(r) = (.1, -.25, .3)$ $a(r) = (.1, .25, .3)$
4.20	8.172	5.589
4.65	8.947	6.120
5.10	9.726	6.653
5.55	10.509	7.188
6.00	12.069	8.255

Table 27. Influence of yearling clean fleece weight on breeding ewe and replacement feed cost for different combinations of relationships in a sheep enterprise producing feeder lambs

	Price vector	
Mutton	H M M L	H M M L
Wool	H H L L	H H L L
Feed	H , H H , H	M , M M , M
Ylg. clean fleece weight (lbs.)		
3.75	4.914	4.095
	$a(r_{5:8}, r_{81:41}, r_{141:41}) = a(r)$	
	$a(r) = (0, -.25, 0)$	$a(r) = (0, -.25, .3)$
4.20	4.881	4.067
4.65	4.848	4.040
5.10	4.816	4.013
5.55	4.783	3.986
6.00	4.750	3.958
	$a(r) = (0, 0, 0)$ $a(r) = (.1, 0, 0)$	$a(r) = (0, 0, .3)$ $a(r) = (.1, 0, .3)$
4.20	4.914	4.095
4.65	4.914	4.095
5.10	4.914	4.095
5.55	4.914	4.095
6.00	4.914	4.095
	$a(r) = (0, .25, 0)$	$a(r) = (0, .25, .3)$
4.20	4.946	4.122
4.65	4.979	4.149
5.10	5.012	4.176
5.55	5.044	4.204
6.00	5.077	4.231

Table 27. (Continued)

	Price vector							
Mutton	H	M	M	L	H	M	M	L
Wool	H	H	L	L	H	H	L	L
Feed	H ,	H	H ,	H	M ,	M	M ,	M

Ylg. clean fleece weight (lbs.)		
	a(r) = (.1, -.25, 0)	a(r) = (.1, -.25, .3)
4.20	4.880	4.067
4.65	4.847	4.039
5.10	4.813	4.011
5.55	4.780	3.983
6.00	4.746	3.955
	a(r) = (.1, .25, 0)	a(r) = (.1, .25, .3)
4.20	4.947	4.123
4.65	4.981	4.151
5.10	5.014	4.178
5.55	5.048	4.206
6.00	5.081	4.234

Table 28. Influence of weaning weight on salvage ewe and lamb income for different combinations of relationships in a range sheep enterprise producing milk-fat and feeder lambs

	Price vector			
Mutton	H H	M M	M M	L L
Wool	H H	H H	L L	L L
Feed	H , M	H , M	H , M	H , M
Weaning weight (lbs.)				
74.00	17.517	15.155	14.611	12.039
	$a(r_{5:8}, r_{81:41}, r_{141:10}) = a(r)$			
	a(r) = (0, -.25, 0)		a(r) = (0, -.25, .25)	
	a(r) = (0, 0, 0)		a(r) = (0, 0, .25)	
	a(r) = (0, .25, 0)		a(r) = (0, .25, .25)	
76.25	17.891	15.479	14.923	12.296
79.50	18.256	15.795	15.227	12.546
82.25	18.612	16.103	15.524	12.791
85.00	18.959	16.403	15.813	13.029
87.75	19.297	16.696	16.095	13.261
	a(r) = (.1, -.25, 0)		a(r) = (.1, -.25, .25)	
	a(r) = (.1, 0, 0)		a(r) = (.1, 0, .25)	
	a(r) = (.1, .25, 0)		a(r) = (.1, .25, .3)	
76.25	17.945	15.525	14.967	12.332
79.50	18.365	15.889	15.318	12.621
82.25	18.779	16.247	15.662	12.905
85.00	19.185	16.599	16.001	13.184
87.75	19.585	16.945	16.335	13.459

Table 29. Influence of weaning weight on breeding ewe and replacement feed cost for different combinations of relationships in a sheep enterprise producing milk-fat and feeder lambs

	Price vector	
Mutton Wool Feed	H H M M H H L L H , H H , H	M M L L H H L L M , M M , M
Weaning weight (lbs.)		
74.00	12.430	10.654
	$a(r_{5:8}, r_{81:41}, r_{141:10}) = a(r)$	
	a(r) = (0, -.25, 0) a(r) = (0, 0, 0) a(r) = (0, .25, 0)	a(r) = (0, .25, .25) a(r) = (0, 0, .25) a(r) = (0, .25, .25)
76.75	12.519	10.730
79.50	12.606	10.805
82.25	12.693	10.880
85.00	12.779	10.954
87.75	12.865	11.027
	a(r) = (.1, -.25, 0) a(r) = (.1, 0, 0) a(r) = (.1, .25, 0)	a(r) = (.1, -.25, .25) a(r) = (.1, 0, .25) a(r) = (.1, .25, .25)
76.75	12.521	10.732
79.50	12.611	10.809
82.25	12.700	10.885
85.00	12.788	10.961
87.75	12.875	11.036

Table 30. Influence of weaning weight on wool income for different combinations of relationships in a range sheep enterprise producing milk-fat and feeder lambs

	Price vector	
Mutton	H H M M	M M L L
Wool	H H H H	L L L L
Feed	H , M H , M	H , M H , M
Weaning weight (lbs.)		
74.00	7.996	5.469
$a(r_{5:8}, r_{81:41}, r_{141:10}) = a(r)$		
$a(r) = (0, .25, 0)$ $a(r) = (.1, -.25, 0)$		
76.75	7.948	5.436
79.50	7.899	5.403
82.25	7.851	5.370
85.00	7.803	5.337
87.75	7.755	5.304
$a(r) = (0, -.25, .25)$ $a(r) = (.1, -.25, .25)$		
76.75	7.948	5.436
79.50	7.899	5.403
82.25	7.851	5.370
85.00	8.045	5.503
87.75	7.996	5.469
$a(r) = (0, 0, 0)$ $a(r) = (.1, 0, 0)$		
76.75	7.996	5.469
79.50	7.996	5.469
82.25	7.996	5.469
85.00	7.996	5.469
87.75	7.996	5.469

Table 30. (Continued)

	Price vector	
Mutton Wool Feed	H H M M H H H H H , M H , M	M M L L L L L L H , M H , M
Weaning weight (lbs.)		
	$a(r) = (0, 0, .25)$ $a(r) = (.1, 0, .25)$	
76.75	7.996	5.469
79.50	7.996	5.469
82.25	7.996	5.469
85.00	8.243	5.638
87.75	8.243	5.638
	$a(r) = (0, .25, 0)$ $a(r) = (.1, .25, 0)$	
76.75	8.044	5.502
79.50	8.092	5.535
82.25	8.140	5.568
85.00	8.188	5.601
87.75	8.236	5.633
	$a(r) = (0, .25, .25)$ $a(r) = (.1, .25, .25)$	
76.75	8.044	5.502
79.50	8.092	5.535
82.25	8.140	5.568
85.00	8.441	5.774
87.75	8.491	5.808

Table 31. Influence of weaning weight on salvage ewe and lamb income for different combinations of relationships in a range sheep enterprise producing feeder lambs

	Price vector			
Mutton Wool Feed	H H H H H , M	M M H H H , M	M M L L H , M	L L L L H , M
Weaning weight (lbs.)				
70.00	10.722	9.231	8.896	7.378
	$a(r_{5:8}, r_{81:41}, r_{141:10}) = a(r)$			
	a(r) = (0, -.25, 0) a(r) = (0, 0, 0) a(r) = (0, .25, 0)		a(r) = (0, -.25, .25) a(r) = (0, 0, .25) a(r) = (0, .25, .25)	
72.75	11.123	9.576	9.229	7.653
75.50	11.524	9.922	9.561	7.929
78.25	11.925	10.268	9.894	8.205
81.00	12.327	10.614	10.227	8.481
83.75	12.728	10.960	10.559	8.757
	a(r) = (.1, -.25, 0) a(r) = (.1, -.25, .25) a(r) = (.1, .25, 0)		a(r) = (.1, 0, 0) a(r) = (.1, 0, .25) a(r) = (.1, .25, .25)	
72.75	11.168	9.615	9.266	7.684
75.50	11.618	10.003	9.639	7.994
78.25	12.072	10.394	10.015	8.305
81.00	12.528	10.788	10.394	8.619
83.75	12.989	11.185	10.775	8.936

Table 32. Influence of weaning weight on wool income for different combinations of relationships in a range sheep enterprise producing feeder lambs

	Price vector	
Mutton Wool Feed	H H M M H H H H H , M H , M	M M L L L L L L H , M H , M
Weaning weight (lbs.)		
70.00	7.401	5.062
	$a(r_{5:8}, r_{81:41}, r_{141:10}) = a(r)$	
	a(r) = (0, -.25, 0) a(r) = (.1, -.25, 0)	a(r) = (0, -.25, .25) a(r) = (.1, -.25, .25)
72.75	7.351	5.028
75.50	7.301	4.994
78.25	7.251	4.960
81.00	7.201	4.925
83.75	7.151	4.891
	a(r) = (0, 0, .25) a(r) = (0, 0, 0)	a(r) = (.1, 0, 0) a(r) = (.1, 0, .25)
72.75	7.401	5.062
75.50	7.401	5.062
78.25	7.251	4.960
81.00	7.201	4.925
83.75	7.151	4.891
	a(r) = (0, .25, 0) a(r) = (.1, .25, 0)	a(r) = (0, .25, .25) a(r) = (.1, .25, .25)
72.75	7.451	5.096
75.50	7.501	5.130
78.25	7.551	5.165
81.00	7.601	5.199
83.75	7.651	5.233

Table 33. Influence of weaning weight on breeding ewe and replacement feed cost for different combinations of relationships in a range sheep enterprise producing feeder lambs

	Price vector	
Mutton	H M M L	H M M L
Wool	H H L L	H H L L
Feed	H , H H , H	M , M M , M
Weaning weight (lbs.)		
70.00	4.914	4.095
	a(r) = (0, -.25, 0) a(r) = (0, 0, 0) a(r) = (0, .25, 0)	a(r) = (0, -.25, .25) a(r) = (0, 0, .25) a(r) = (0, .25, .25)
72.75	4.953	4.127
75.50	4.992	4.160
78.25	5.030	4.192
81.00	5.068	4.223
83.75	5.106	4.255
	a(r) = (.1, -.25, 0) a(r) = (.1, 0, 0) a(r) = (.1, .25, 0)	a(r) = (.1, -.25, .25) a(r) = (.1, 0, .25) a(r) = (.1, .25, .25)
72.75	4.954	4.128
75.50	4.993	4.161
78.25	5.033	4.194
81.00	5.072	4.226
83.75	5.110	4.259

Table 34. Influence of yearling grease fleece weight on salvage ewe and lamb income for different combinations of relationships in a farm flock sheep enterprise

	Price vector			
Mutton	H H	M M	M M	L L
Wool	H H	H H	L L	L L
Feed	H , M	H , M	H , M	H , M
Ylg. grease fleece weight (lbs.)				
9.0	21.643	18.949	18.317	15.154
	$a(r_{81:181}, r_{18:5}) = a(r)$			
		$a(r) = (0, 0)$		
9.5	21.643	18.949	18.317	15.154
10.0	21.643	18.949	18.317	15.154
10.5	21.643	18.949	18.317	15.154
11.0	21.643	18.949	18.317	15.154
11.5	21.643	18.949	18.317	15.154
		$a(r) = (0, .25)$		
9.5	22.154	19.396	18.749	15.511
10.0	22.665	19.844	19.181	15.867
10.5	23.176	20.291	19.613	16.224
11.0	23.687	20.739	20.045	16.581
11.5	24.197	21.186	20.477	16.937
		$a(r) = (.5, 0)$		
9.5	21.660	18.963	18.332	15.167
10.0	21.667	18.978	18.346	15.179
10.5	21.693	18.992	18.361	15.192
11.0	21.710	19.007	18.375	15.204
11.5	21.727	19.021	18.390	15.217

Table 34. (Continued)

	Price vector			
Mutton	H H	M M	M M	L L
Wool	H H	H H	L L	L L
Feed	H , M	H , M	H , M	H , M
Ylg. grease fleece weight (lbs.)				
		a(r) = (.5, .25)		
9.5	22.171	19.411	18.764	15.523
10.0	22.698	19.873	19.210	15.893
10.5	23.226	20.335	19.657	16.262
11.0	23.754	20.797	20.103	16.631
11.5	24.281	21.259	20.550	17.000

Table 35. Influence of yearling grease fleece weight on wool income for different combinations of relationships in a farm flock sheep enterprise

	Price vector	
Mutton	H H M M	M M L L
Wool	H H H H	L L L L
Feed	H , M H , M	H , M H , M
Ylg. grease fleece weight (lbs.)		
9.0	6.961	4.760
	$a(r_{81:181}, r_{18:5}) = a(r)$	
	$a(r) = (0, 0)$ $a(r) = (.5, 0)$	$a(r) = (0, .25)$ $a(r) = (.5, .25)$
9.5	7.303	4.994
10.0	7.645	5.228
10.5	7.988	5.462
11.0	8.330	5.696
11.5	8.672	5.930

Table 36. Influence of yearling grease fleece weight on breeding ewe and replacement feed cost for different combinations of relationships in a farm flock sheep enterprise

	Price vector	
Mutton	H M M L	H M M L
Wool	H H L L	H H L L
Feed	H , H H , H	M , M M , M
Ylg. grease fleece weight (lbs.)		
9.0	16.239	13.533
	$a(r_{81:181}, r_{18:5}) = a(r)$	
	$a(r) = (0, 0)$	
9.5	16.239	13.533
10.0	16.239	13.533
10.5	16.239	13.533
11.0	16.239	13.533
11.5	16.239	13.533
	$a(r) = (0, .25)$	
9.5	16.262	13.552
10.0	16.285	13.571
10.5	16.309	13.590
11.0	16.332	13.610
11.5	16.355	13.629
	$a(r) = (.5, 0)$	
9.5	16.414	13.678
10.0	16.588	13.823
10.5	16.762	13.969
11.0	16.937	14.114
11.5	17.111	14.259

Table 36. (Continued)

	Price vector							
Mutton	H	M	M	L	H	M	M	L
Wool	H	H	L	L	H	H	L	L
Feed	H ,	H	H ,	H	M ,	M	M ,	M
Ylg. grease fleece weight (lbs.)								
	a(r) = (.5, .25)							
9.5	16.437				13.697			
10.0	16.634				13.862			
10.5	16.832				14.027			
11.0	17.030				14.191			
11.5	17.227				14.356			

Table 37. Influence of yearling grease fleece weight on lamb feed cost for different combinations of relationships in a farm flock sheep enterprise

	Price vector	
Mutton	H M M L	H M M L
Wool	H H L L	H H L L
Feed	H , H H , H	M , M M , M
Ylg. grease fleece weight (lbs.)		
9.0	5.799	5.075
	$a(r_{81:181}, r_{18:5}) = a(r)$	
	$a(r) = (0, 0)$ $a(r) = (.5, 0)$	
9.5	5.799	5.075
10.0	5.799	5.075
10.5	5.799	5.075
11.0	5.799	5.075
11.5	5.799	5.075
	$a(r) = (0, .25)$ $a(r) = (.5, .25)$	
9.5	5.828	5.099
10.0	5.855	5.123
10.5	5.881	5.146
11.0	5.906	5.168
11.5	5.930	5.189

Table 38. Influence of lambing rate on salvage ewe and lamb income for different combinations of relationships in a farm flock sheep enterprise

	Price vector			
Mutton	H H	M M	M M	L L
Wool	H H	H H	L L	L L
Feed	H , M	H , M	H , M	H , M
Lambing rate (%)				
140	21.643	18.949	18.317	15.154
	$a(r_{5:8}, r_{18:5}) = a(r)$			
		$a(r) = (0, 0)$ $a(r) = (0, .25)$		
145	22.555	19.748	19.089	15.791
150	23.468	20.547	19.860	16.428
155	24.380	21.346	20.361	17.065
160	25.292	22.145	21.402	17.702
165	26.204	22.944	22.174	18.338
		$a(r) = (.1, 0)$ $a(r) = (.1, .25)$		
145	22.557	19.749	19.090	15.792
150	23.471	20.550	19.862	16.430
155	24.384	21.350	20.635	17.068
160	25.298	22.150	21.408	17.706
165	26.212	22.951	22.180	18.344

Table 39. Influence of lambing rate on wool income for different combinations of relationships on a farm flock sheep enterprise

	Price vector	
Mutton	H H M M	M M L L
Wool	H H H H	L L L L
Feed	H , M H , M	H , M H , M
Lambing rate (%)		
140	6.961	4.760
	$a(r_{5:8}, r_{18:5}) = a(r)$	
	$a(r) = (0, 0)$ $a(r) = (.1, 0)$	
145	6.961	4.760
150	6.961	4.760
155	6.961	4.760
160	6.961	4.760
165	6.961	4.760
	$a(r) = (0, .25)$ $a(r) = (.1, .25)$	
145	6.997	4.785
150	7.032	4.809
155	7.068	4.834
160	7.104	4.858
165	7.140	4.883

Table 40. Influence of lambing rate on breeding ewe and replacement feed cost for different combinations of relationships in a farm flock sheep enterprise

	Price vector	
Mutton Wool Feed	H M M L H H L L H , H H , H	M M L L H H L L M , M M , M
Lambing rate (%)		
140	16.239	13.533
	$a(r_{5:8}, r_{18:5}) = a(r)$	
	$a(r) = (0, 0)$ $a(r) = (0, .25)$	
145	16.281	13.567
150	16.332	13.602
155	16.363	13.636
160	16.405	13.671
165	16.446	13.705
	$a(r) = (.1, 0)$ $a(r) = (.1, .25)$	
145	16.296	13.580
150	16.353	13.628
155	16.410	13.675
160	16.467	13.723
165	16.524	13.770

Table 41. Influence of lambing rate on lamb feed cost for different combinations of relationships in a farm flock sheep enterprise

	Price vector	
Mutton	H M M L	H M M L
Wool	H H L L	H H L L
Feed	H , H H , H	M , M M , M
Lambing rate (%)		
140	5.799	5.075
	$a(r_{5:8}, r_{18:5}) = a(r)$	
	a(r) = (0, 0) a(r) = (.1, 0)	a(r) = (0, .25) a(r) = (.1, .25)
145	5.849	5.118
150	5.896	5.159
155	5.939	5.196
160	5.980	5.232
165	6.018	5.265